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EXPANSIONARY YET DIFFERENT: CREDIT SUPPLY AND REAL EFFECTS OF NEGATIVE INTEREST RATE POLICY

Margherita Bottero, Camelia Minoiu, José Luis Peydró, Andrea Polo, Andrea Presbitero and Enrico Sette

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Centre for Economic Policy Research
33 Great Sutton Street, London EC1V 0DX, UK
Tel: +44 (0)20 7183 8801
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Abstract

We show that negative interest rate policy (NIRP) has expansionary effects on bank credit supply—and the real economy—through a portfolio rebalancing channel, and that, by shifting down and flattening the yield curve, NIRP differs from rate cuts just above the zero lower bound. For identification, we exploit ECB's NIRP and matched administrative datasets—including the credit register—from Italy, severely hit by the Eurozone crisis. NIRP affects banks with higher ex-ante net short-term interbank positions or, more broadly, more liquid balance-sheets. NIRP-affected banks rebalance their portfolios from liquid assets to lending, especially to ex-ante riskier and smaller firms—without higher ex-post delinquencies—and cut loan rates (even to the same firm), inducing sizable firm-level real effects. By contrast, there is no evidence of a retail deposits channel associated with NIRP.

JEL Classification: E52, E58, G01, G21, G28

Keywords: Negative Interest Rates, Portfolio rebalancing, bank lending channel of monetary policy, Liquidity management, eurozone crisis

Margherita Bottero - margherita.bottero@bancaditalia.it
Bank of Italy

Camelia Minoiu - camelia.minoiu@frb.gov
Federal Reserve Board

José Luis Peydró - jose.peydro@gmail.com
Imperial College London, ICREA-UPF-CREi-Barcelona GSE and CEPR and CEPR

Andrea Polo - apolo@luiss.it
LUISS, UPF, Barcelona GSE, EIEF and CEPR

Andrea Presbitero - apresbitero@imf.org
IMF and MoFiR

Enrico Sette - enrico.sette@bancaditalia.it
Bank of Italy

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Expansionary Yet Different: Credit Supply and Real Effects of Negative Interest Rate Policy*

Margherita Bottero, Camelia Minoiu, José-Luis Peydró, Andrea Polo, Andrea F. Presbitero, Enrico Sette

Abstract

We show that negative interest rate policy (NIRP) has expansionary effects on bank credit supply—and the real economy—through a portfolio rebalancing channel, and that, by shifting down and flattening the yield curve, NIRP differs from rate cuts just above the zero lower bound. For identification, we exploit ECB's NIRP and matched administrative datasets—including the credit register—from Italy, severely hit by the Eurozone crisis. NIRP affects banks with higher ex-ante net short-term interbank positions or, more broadly, more liquid balance-sheets. NIRP-affected banks rebalance their portfolios from liquid assets to lending, especially to ex-ante riskier and smaller firms—without higher ex-post delinquencies—and cut loan rates (even to the same firm), inducing sizable firm-level real effects. By contrast, there is no evidence of a retail deposits channel associated with NIRP.

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*Authors' contacts: Margherita Bottero, Bank of Italy, e-mail: margherita.bottero@bancaditalia.it; Camelia Minoiu, Federal Reserve Board, e-mail: camelia.minoiu@frb.gov; José-Luis Peydró, Imperial College London, ICREA-UPF-CREi-Barcelona GSE, CEPR, e-mail: jose.peydro@gmail.com; Andrea Polo, LUISS, UPF, Barcelona GSE, EIEF, CEPR, ECGI, e-mail: andreapolo@gmail.com; Andrea F. Presbitero, International Monetary Fund and MoFiR, e-mail: apresbitero@imf.org; Enrico Sette, Bank of Italy, e-mail: enrico.sette@bancaditalia.it. This draft is from December 13, 2019. We thank David Arseneau, Gabriel Chodorow-Reich, Vitor Costancio, Giovanni Dell'Ariccia, Davide Fantino, Dimas Mateus Fazio, Xavier Freixas, Luca Fornaro, Michael Gofman, Charles, Goodhart, Lucyna Gornicka, Yuriy Gorodnichenko, Luca Guerrieri, Florian Heider, Tumer Kapan, Kebin Ma, David Martinez Miera, Emi Nakamura, Marco Pagano, Daniel Paravisini, Rafael Repullo, Ken Rogoff, Kasper Roszbach, Marcelo Ulate, William White, and participants at the 2019 NBER Summer Institute (Monetary Economics) and numerous conferences and seminars for useful comments and discussions. Camelia Minoiu is grateful to the Wharton Financial Institutions Center and the Management Department at the University of Pennsylvania for their hosting during the development of this research project. This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No 648398). Peydró also acknowledges financial support from the ECO2015-68182-P (MINECO/FEDER, UE) grant and the Spanish Ministry of Economy and Competitiveness, through the Severo Ochoa Programme for Centres of Excellence in R&D (SEV-2015-0563). The views expressed herein are those of the authors and should not be attributed to the Bank of Italy, the Federal Reserve Board, the IMF, their management, or policies.

"Negative [policy] rates were introduced for one specific reason: when interest rates reached the zero lower bound, the expectations for the future rates in the long term are only that the rates can go up. So with negative rates we were successful in taking these expectations down"

"By and large our negative interest-rate policies have been a success. [...] *We haven't seen bank profitability going down; in fact it is going up."*

Mario Draghi (2016, 2017), President of the European Central Bank

1 Introduction

Negative nominal interest rates are a significant innovation in monetary policy-making, with important implications for finance and macroeconomics. Long thought as unrealistic, negative interest rate policy (NIRP) was recently adopted in several advanced economies by paying negative rates on *bank* deposits at central banks. The first central bank to do so was the Danish National Bank in 2012, followed by the European Central Bank (ECB), the Swiss National Bank, the Sveriges Riksbank, and the Bank of Japan. NIRP may become even more important given that current interest rates are low and central banks may need to further cut rates.[1] Moreover, from a theoretical point of view, the effects of NIRP on the economy are a priori unclear. While negative rates may boost aggregate demand by removing the zero lower bound (ZLB) (Bernanke, 2017; Rogoff, 2016, 2017), they could also be contractionary through bank lending (Brunnermeier and Koby, 2018; Eggertsson et al., 2019). Despite the importance of NIRP for the broader understanding of finance and macroeconomics, systematic evidence on its transmission to the economy through the banking system remains scarce.

The introduction of NIRP as an unconventional tool of monetary policy raises two major questions. First, what is the impact of this policy on credit supply and the real economy? Second, do negative monetary policy rates differ in their transmission to the economy from conventional rate cuts just above the ZLB, and from other unconventional monetary policies, such as quantitative easing (QE)? In this paper, we answer these questions by exploiting the ECB's introduction of negative nominal policy rates in mid-2014 (as well as other policy rate cuts) and Italian administrative data on loan volumes and lending rates from the credit register, matched with firm- and bank-level balance sheet data. As part of a monetary union, Italy provides an excellent setting to study NIRP in the context of contracting GDP in 2012 and 2013, while the ECB's balance sheet was shrinking and euro area monetary conditions were tighter than in several other countries.

In brief, we find an increase in total bank credit growth after the introduction of NIRP using

[1] Since 1970 policy rates have been cut by more than 500 basis points in response to recessions in the U.S. and the euro area (Eggertsson et al., 2019). Moreover, in 2019 both the US and euro area (as well as many other countries) have significantly cut monetary policy rates (in parallel with downward revisions in GDP growth forecasts).

aggregate time-series data. The announcement of NIRP shifted down and flattened the risk-free yield curve, widening the spread between the yields of safer, liquid assets and those of corporate loans. Thus, we find that NIRP affected relatively more those banks with higher ex-ante net short-term interbank positions (as short-term interbank rates became negative) or, more broadly, those banks with more liquid balance-sheets (since the change in the yield curve affected *all* maturities).

A loan-level analysis shows that more NIRP-affected banks cut liquid assets and expand credit supply more, in particular to ex-ante riskier and smaller firms—without higher ex-post non-performing loans (NPLs)—and cut loan rates, inducing sizable firm-level real effects. Our evidence is inconsistent with the view that banks that rely more on retail deposits change (reduce) the supply of credit volumes, or loan rates, in response to NIRP; instead, we show that banks preserve margins and profitability, also by raising fees on bank deposits. Moreover, previous monetary policy rate cuts in positive territory close to the ZLB were unable to flatten the yield curve and did not cause a similar rebalancing of bank portfolios; differently from the announcements of QE in January 2015 and the most recent policy negative rate cut in March 2016, both of which were associated with further flattening of the yield curve and portfolio rebalancing.[2]

Our main contribution to the literature is to document that NIPR has expansionary effects, and yet differs from rate cuts just above the ZLB. The mechanism at work is via shifting down and flattening the yield curve, and hence incentivizing banks to rebalance their portfolio from liquid assets to credit supply. Furthermore, we show that the bank lending channel of NIRP is different from the traditional channel associated with interest rate cuts above the ZLB (Kashyap and Stein, 1995, 2000; Jiménez et al., 2012; Drechsler et al., 2017). We find no evidence of a retail deposits channel (unlike Eggertsson et al. (2019) and Heider et al. (2019)), even after the last rate cut.[3] Below, we provide a detailed preview of the paper and discuss the novelty of our findings in relation to the literature.

Detailed preview of the paper. Macroeconomic theory argues that a policy rate cut expands aggregate demand (thereby boosting economic growth and prices), hence it finds in the ZLB an important constraint in a situation of adverse economic conditions (Bernanke, 2017; Rogoff, 2016, 2017; Dell'Ariccia et al., 2018). As shown in the opening quotes, Draghi (2017) argues that NIRP has had positive effects. However, other central banks, including the U.S. Federal Reserve and the Bank of

[2] In September 2019 the ECB further reduced the negative rate, but data to analyze this additional cut are not yet available. The ECB also changed the implementation of the policy by introducing a two-tier system for reserve remuneration, exempting parts of banks' liquidity holdings from negative remuneration.

[3] The results on the portfolio rebalancing and the retail deposits channels are not specific to the Italian context, as they are confirmed by a bank-level analysis for the entire euro area.

England, have been less keen to adopt this policy (Bernanke, 2016).[4] One reason is that the positive aggregate demand channel could be offset by a contraction in credit supply due to the adverse effect of NIRP on banks' net worth (Eggertsson et al., 2019; Sims and Wu, 2019; Ulate, 2019). Brunnermeier and Koby (2018) theoretically show that there may be a "reversal" interest rate beyond which lower rates undo the cut's intended effects on bank lending and become contractionary. This reversal rate is a low interest rate, potentially even negative. Very low interest rates are also believed to drive financial intermediary reach-for-yield behavior (Rajan, 2005; Taylor, 2009; Allen and Rogoff, 2011; Stein, 2013; Martinez-Miera and Repullo, 2017), consistent with a risk-taking channel of monetary policy (Adrian and Shin, 2010; Borio and Zhu, 2012).

Negative policy rates can affect the real economy through the banking system primarily through two, non-mutually exclusive, channels. A first channel of transmission hinges on the pass-through of negative policy rates to bank retail deposit rates ("retail deposits channel"). Given that banks are generally reluctant to charge negative rates on retail deposits, NIRP may reduce banks' net interest margins and profits, eroding their capital and reducing their lending capacity. This phenomenon should be more pronounced for banks that are more dependent on retail deposits, leading them to curtail credit and take more risk (Heider et al., 2019) or/and to weaken the pass-through to loan rates (Eggertsson et al., 2019). By contrast, other studies argue that the contractionary effects of NIRP could be relatively small. Ulate (2019), for instance, calibrates a DSGE model with monopolistic competition in the banking sector to show that the adverse effect of negative rates on bank profitability is dampened by the increase in aggregate demand, which allows banks to switch from reserves to loans. In addition, the monetary transmission mechanisms would not be impaired if banks passed negative rates to some retail depositors—as shown for a set of sound European banks by Altavilla et al. (2019)—or if banks with large retail deposits simultaneously charged higher fees to preserve profitability (Altavilla et al., 2018; IMF, 2016; Lopez et al., 2018).

An alternative transmission channel works through portfolio rebalancing actions by banks with safer, more liquid assets. Negative interest rates penalize the holdings of such assets, incentivizing banks to shift their portfolios away from low- or negative-yield liquid assets towards higher-yield

[4] Bernanke (2016) on the views of the Federal Reserve's decision body (Federal Open Market Committee, FOMC) and the Bank of England regarding NIRP: "*Interestingly, some advocates of a higher inflation target have been dismissive of the use of negative short-term interest rates, an alternative means of increasing "space" for monetary easing [...] Williams said: "Negative rates are still at the bottom of the stack in terms of net effectiveness." Williams's colleague on the FOMC, Eric Rosengren, has suggested that [...] negative rates should be viewed as a last resort. My sense is that Williams's and Rosengren's negative view of negative rates is broadly shared on the FOMC. Outside the United States, Mark Carney, governor of the Bank of England [...] has indicated he was "not a fan" of negative interest rates.*"

assets such as corporate loans (a "portfolio rebalancing channel", see e.g., Bernanke (2016); Rostagno et al. (2016)). In the words of Brunnermeier and Koby (2018): *"as yields on safe assets decrease, banks decrease their lending rates for risky loans in order to substitute their safe assets positions into riskier high-yield ones, another effect which the central bank seeks to induce."* This would be especially the case if NIRP moves the entire yield curve downward—after breaking through the ZLB, market participants may expect rates to stay low or negative for long (see Draghi's 2016 initial quote). The fall in the yield of safer assets of all maturities would widen the wedge between safer, more liquid and riskier, more illiquid assets, and may lead banks to rebalance their portfolio to preserve profitability. According to this logic, a policy rate cut into negative territory would work differently from regular policy rate cuts (in positive territory) in the proximity of the ZLB, but similarly to QE given the accompanying flattening of the yield curve,[5] and increase in the safety premium (see Krishnamurthy and Vissing-Jorgensen (2011) for the U.S.). Furthermore, portfolio rebalancing toward loans can additionally be incentivized by a reduction in the risk of corporate loans. The announcements of NIRP, or of QE, are large monetary policy shocks—they flatten the yield curve—so they are able to promote recovery in the real economy, thereby raising corporate profits and reducing corporate delinquency and default rates (Chodorow-Reich, 2014).

Italy provides an ideal set-up for the analysis of NIRP because of its administrative datasets and specific context. We use the supervisory credit register of the Bank of Italy, which offers detailed information on bank loans to all Italian firms, and from which we obtain outstanding loan *volumes* and lending *rates* at the *firm-bank-month* level. This is a major data advantage as loan rates are absent in most the credit registers around the world. We double-match this dataset with detailed firm and bank balance sheet information to study the effects of NIRP on both firms and banks that are connected through credit relationships. Data on bank balance sheets come from supervisory reports, while data on firm financials are obtained from the official balance sheet data deposited by firms to the Chambers of Commerce, as required by Italian law. These datasets allow us to conduct a comprehensive analysis of bank asset allocations and their spillovers to the real economy when policy rates turn negative.

Italy is a large European economy where the banking sector provides the bulk of firm financing and is part of a monetary union—i.e., Italian banks are affected by the monetary policies of the European Central Bank for the *entire* euro area. The euro area sovereign debt crisis had a strong impact on Italy, triggering a deep recession in 2012 and 2013 with substantial economic slack. Importantly, the

[5] See, e.g. Gambetti and Musso (2017); Altavilla et al. (2015) for the euro area; D'Amico and King (2013) for the U.S.

difference in GDP growth between the euro area and Italy was highest during this period since the introduction of the euro in 1999. At the same time, the size of the ECB balance sheet was *decreasing*, while those of the U.S. Federal Reserve and Bank of England were *growing*.[6] However, just prior to NIRP, euro area inflation was very low and decreasing over 2014, hence the ECB decided to introduce negative rates in mid-2014 (in fact, there was deflation in the euro area in that year).

Our empirical approach exploits cross-sectional variation in ex-ante exposure to NIRP across banks in a difference-in-differences framework. Thanks to the granularity of the data, in our lending regressions we identify bank credit supply by exploiting both loan-level volumes and prices, and by including firm fixed effects, which allow us to keep constant firm-level credit demand and other firm fundamentals (Khwaja and Mian, 2008). This approach is key for identification, as monetary policy impacts both the supply and demand of credit through the bank lending and firm borrowing channels. To identify the portfolio rebalancing channel, we focus on two bank-level exposure variables: the net interbank position and the liquid balance sheet position. First, the banks' interbank position, a narrower measure of exposure to NIRP, is computed as interbank loans minus deposits with maturity of up to one week (measured before the NIRP announcement and divided by total assets). We adopt this measure because interest rates on interbank funding up to one week became negative soon after the introduction of the policy. In addition, interbank activity in Italy (and in Europe in general) is sizeable. Second, the banks' liquid balance sheet position, a broader measure of exposure to NIRP, is defined as the ratio of securities over assets, as in the literature on the bank lending channel of monetary policy (following Kashyap and Stein, 2000). This measure is relatively more encompassing in terms of asset size, types, and maturities, and represents 29% of total assets for the average Italian bank. We adopt this measure because the change of the yield curve induced by NIRP affected *all* maturities and it is a key measure of the bank lending channel of monetary policy.[7]

We now describe the main results in more detail. Analyzing time series data, total bank credit growth increases after the introduction of NIRP. This development is not specific to Italy since credit growth picked up in the entire euro area after the introduction of NIRP (Cœuré, 2016). In addition, banks with larger ex-ante net interbank position cut interbank loans after the introduction of negative

[6] A key element was that, while the ECB had not yet introduced large scale asset purchases (LSAP), the Federal Reserve and Bank of England had already done QE, the Federal Reserve even had QE3 in 2012-2013.

[7] In the robustness section we show that our results are not simply driven by windfall gains associated with the repricing of securities due to the NIRP announcement. Additionally, our estimates of the impact of NIRP are different from those when policy rate cuts are above the ZLB, which are also associated with windfall gains. Note further that lower monetary policy rates benefit both securities (via prices) and also loans (e.g., via a reduction in provisioning, delinquencies and write-offs); in addition, most securities held by banks are not held in the trading book.

policy rates. Similarly, banks with higher liquidity reduce the share of liquid assets in their portfolio after the introduction of NIRP. Using micro data from the credit register, we find that NIRP-affected banks (i.e., those with larger ex-ante net interbank position or more liquid balance sheet) increase their supply of corporate loans more than other banks during the same period. This effect is present as early as 1 month after the implementation of the policy and persists for at least 6 months. We also show that NIRP-affected banks reduce the interest rates they charge on corporate loans: a change of one standard deviation in the banks' net interbank position (or liquidity) leads to a 4% reduction in lending rates. Hence, holding constant firm fundamentals, credit supply improves both by way of higher loan volumes and lower prices. All these results lend support to the presence of a portfolio rebalancing channel.

Notably, we find no systematic evidence of a retail deposits channel associated with NIRP, as the supply of credit—both volumes and loan rates—by banks with larger retail deposits does not change after the introduction of NIRP (nor after the last rate cut for which data are available). We also show that banks with larger retail deposits increase fees for deposits-related banking services and do not suffer a compression in intermediation margins and profitability after NIRP.

To address potential external validity concerns, we conduct a bank-level analysis for the entire euro area and find similar results. More liquid banks expand lending after NIRP relatively more than other banks, consistent with the portfolio rebalancing channel documented for Italy. Further, we find no evidence of a retail deposits channel in the sample of euro area banks.

The loan-level analysis for Italy also shows that NIRP-affected banks *further* rebalance their assets by taking more risk in their loan portfolios: the relative increase in loan supply is stronger vis-a-vis ex-ante smaller and riskier firms (where firm risk is measured by credit ratings). We find no evidence that this increase in ex-ante risk taking translates into higher ex-post NPLs, even after 5 years. Therefore, greater bank risk-taking after NIRP is consistent with higher credit supply to ex-ante more constrained, but viable firms.

The increase in credit supply by NIRP-affected banks leads to sizable firm-level real effects. A one standard deviation increase in banks' net interbank position (liquidity) is associated with a 2.5 (1.0) percentage point increase in total credit. In addition, more bank credit translates into stronger firm performance, as firms borrowing more from lenders with greater ex-ante exposure to NIRP expand economic activity relatively more. A one standard deviation increase in banks' net interbank position (liquidity) is associated with an increase in firms' investments by 6.8 (4.6) percentage points and in the wage bill by 3.8 (1.0) percentage points.

Taken together, our results suggest that banks which are relatively more affected by negative interest rates rebalance their portfolios away from lower yield assets (such as short-term interbank claims or, more broadly, liquid holdings) towards higher yield assets (such as corporate loans). Within corporate loans, they extend more loans to *ex-ante* riskier and smaller, yet viable firms (as there is no increase in ex-post NPLs). Greater credit supply improves borrowing conditions for firms, which in turn are better able to expand their activities, with beneficial effects for the real economy.

Falsification tests show that our results are not driven by systematic differences across banks in their lending to firms with specific characteristics, nor by prior trends. Our results survive a battery of robustness tests, including controlling for other unconventional monetary policies, such as the Targeted Longer-Term Refinancing Operations (TLTRO), which were implemented a few months after NIRP. Our results also hold in a narrowly-defined time window, which minimizes the potential effect of confounding policies.

Our analysis suggests that NIRP works differently from conventional monetary policy. The standard bank lending channel postulates that monetary easing has a greater impact on credit supply for banks with *lower* liquid-to-total assets ratios (Kashyap and Stein, 1995, 2000; Jiménez et al., 2012).[8] This is indeed what we find even for the previous rate cuts just above the ZLB, both for the 2012 deposit facility (DF) rate cut and the 2013 main refinancing operation (MRO) rate cut. By contrast, an interest rate cut into negative territory works *differently*, with stronger effects for banks with *larger* liquid-to-total assets ratios.

We document that the introduction of NIRP steered market expectations by removing the ZLB, inducing a downward shift and a simultaneous flattening of the yield curve (see also: Draghi, 2016; Cœuré, 2017; Grisse et al., 2017), which previous rate cuts above the ZLB had been unable to achieve.[9] Moreover, we further document that the decline in the yields of safer, liquid assets of all maturities widened the wedge vis-a-vis yields on riskier assets, incentivizing banks to rebalance their portfolios. We find similar results for the last rate cut (with available data) in March 2016.

Finally, we show that also the ECB's January 2015 announcement of QE policies is associated with a strong flattening of the yield curve and bank portfolio rebalancing effects. Despite the fact

[8] Drechsler et al. (2017) focus on the effect of market power in the deposits market as opposed to that of bank balance sheet liquidity.

[9] Before the announcement of NIRP, with the overnight interest rate at the perceived lower bound, the distribution of future possible rates is truncated: expected future short-term interest rates can only increase. The announcement of negative rates removes the perception of the lower bound at zero and hence change the distribution of expected future short-term interest. Christensen (2019) shows that the yield curve flattened after the announcement of NIRP in all countries which adopted negative rates (not only Euro area but also Denmark, Sweden, Switzerland and Japan).

that both QE and NIRP announcements flattened the yield curve, the two policies differ as NIRP was additionally associated with a drop in very short-term rates, which penalizes holdings of very short-term interbank claims even more than QE. As a result, we find that the coefficient estimate on bank liquidity is similar around QE and NIRP announcements, but the coefficient on the net interbank position is smaller and insignificant for QE compared to its NIRP counterpart.

Contribution to the literature. Our main contribution to the literature is to show expansionary effects of NIRP, yet different from rate cuts just above the ZLB. By shifting down and flattening the yield curve, NIRP activated a portfolio rebalancing channel. On the other hand, we do not find evidence of a retail deposits channel associated with NIRP. Our evidence that negative rates are expansionary through banks lends support to the view that monetary policy does not necessarily become ineffective at the ZLB (Rognlie, 2016; Swanson, 2018; Debortoli et al., 2019). We also provide estimates of the elasticity of credit with respect to bank balance sheet variables that capture different transmission channels of NIRP to lending. Thus, our results inform macro models on the transmission of NIRP to the real economy through the bank lending channel, in the spirit of Nakamura and Steinsson (2018), and support models that emphasize the portfolio rebalancing effects of NIRP over the retail deposits channel, with an expansionary effect on lending and the real economy.

Our analysis adds to several recent studies of the impact of NIRP on bank lending. Eggertsson et al. (2019) examine the effects of NIRP through the retail deposits channel. Using bank-level data and variation in the share of deposit funding across Swedish banks, the authors document a weakening pass-through from the policy rate to loan rates during the NIRP period. By contrast, we use *loan-level* data and document a *strong* pass-through from negative policy rates to loan rates while controlling for shifts in unobserved time-varying firm-level characteristics. Heider et al. (2019) examine the effects of negative rates *from June 2014* on syndicated loans in the euro area. Based on a difference-in-differences estimation that exploits variation in reliance on retail deposits across banks as a measure of exposure to NIRP, the authors show that banks with more retail deposits (hence more constrained in passing negative rates to depositors) reduce syndicated loan growth and take more risk than other banks. In our analysis, based on more granular and comprehensive data from a country with a large presence of bank-dependent small and medium-sized firms, the retail deposits channel is inactive. In addition, we show that NIRP has expansionary effects on credit supply and, in turn on the real economy, through a portfolio rebalancing channel.[10]

[10] Basten and Mariathasan (2018) and Demiralp et al. (2019) use bank-level data and take excess reserves at the central

Our paper further contributes to the broader literature on unconventional monetary policy, which focuses on more common policies such as large-scale asset purchases, large liquidity injections and forward guidance (see, among others, Bhattarai and Neely (2016); Chakraborty et al. (2019); and Rodnyansky and Darmouni (2017) for U.S. policies; and Acharya et al. (2016); Acharya et al. (2019) and Peydró et al. (2017) for European policies).[11] Finally, our paper adds to the literature on the risk-taking channel of monetary policy (see Adrian and Shin, 2010; Jiménez et al., 2014; Dell'Ariccia et al., 2017, among others). Our main contribution to these two strands of literature is to analyze the portfolio rebalancing channel of *negative* interest rates, its effects on bank credit and the real economy and show why NIRP differs from previous rate cuts above the ZLB.

The remainder of the paper is organized as follows. Section 2 discusses the negative interest rate policy of the ECB. Section 3 describes the data, hypotheses, and empirical approach. Sections 4 and 5 document the effects of NIRP on credit supply and firm-level outcomes. Section 6 concludes.

2 Institutional Background

In this section we discuss the institutional context in which the ECB introduced NIRP and the details of its implementation. In doing so, we lay out the key elements of our empirical strategy.

Italy is a part of a monetary union, and hence unlike most countries around the world (such as US, UK, Japan, etc.), monetary policy is not decided by its own central bank, but by the European Central Bank for the entire euro area. Before NIRP, monetary conditions had been tighter in Italy than in

bank as a measure of sensitivity to negative policy rates. In Italy, excess reserves are close to zero. Demiralp et al. (2019) show that European banks with more excess liquidity expand lending, consistent with our results about a portfolio rebalancing channel. They find no evidence of a retail deposits channel. Basten and Mariathasan (2018) look at the case of Switzerland to examine a policy decision aimed at mitigating currency appreciation in a safe-haven country facing strong capital inflows. They find that bank profitability is unaffected by NIRP, as banks offset lower-interest margins with higher fees, but banks take more risk. Arseneau (2017) uses supervisory data from the U.S. bank stress tests, in which U.S. banks are asked about the balance sheet impact of *hypothetical* NIRP, and finds that U.S. banks vary significantly in their exposure to negative rates and the effect of NIRP on bank margins would depend on their liquidity provision. Altavilla et al. (2019) show that negative rates in Europe have an expansionary effect through a corporate channel, as firms more exposed to the policy (holding cash at banks that pass through negative rates to depositors) rebalance their portfolio from cash and short-term assets to investment. None of these studies use micro data at loan level, so they cannot control for unobserved time-varying firm-level characteristics such as credit demand and risk. Finally, Arce et al. (2018) compare the lending behavior of Spanish banks that reported to the ECB's Bank Lending Survey their views on the incidence of NIRP on net interest income in April 2016 (that is, two years *after* the introduction of NIRP). Their analysis shows that the banks which reported profitability had been negatively impacted by this policy took less risk in their loan portfolio and that credit supply did not change differentially across banks. Compared to the approach of this paper, our measures of bank exposure to NIRP are computed prior to the policy (not ex-post), they are grounded in a specific transmission channel of monetary policy (namely, the portfolio rebalancing channel), and they rely on supervisory data as opposed to being self-reported.

[11] For theoretical contributions on unconventional monetary policy, see Gertler and Karadi (2011), Curdia and Woodford (2011) and McKay et al. (2016), among others.

several other European countries and the U.S.[12] In Italy, GDP growth was negative in both 2012 and 2013. At that time, the ECB had not yet introduced QE and its balance sheet was shrinking (partly due to early LTRO repayments). By contrast, the U.S. Federal Reserve and the Bank of England already had introduced large scale asset purchase programs (LSAPs) and their balance sheets were expanding. Against the backdrop of negative GDP growth and low and declining inflation in 2013,[13] the ECB decided to cut rates into negative territory in mid-2014. These developments suggest that ECB's monetary policy in June 2014 did not directly address the macroeconomic context in Italy, but rather the slowdown in economic recovery in the euro area as a whole, with the goal of maintaining price stability in the area.

The ECB is not the only central bank to implement NIRP. Since 2012, other major central banks around the world have adopted negative monetary policy rates in an effort to either further ease monetary conditions and to support economic activity (e.g., Japan) or to limit capital inflows and related exchange rate appreciation (e.g., Switzerland and Denmark). In August 2019, monetary rates were negative in countries accounting for 25% of world GDP and the amount of debt globally trading at negative yields reached USD 17 trillion.[14] On June 11, 2014, the ECB reduced the deposit facility (DF) rate—the rate it pays on overnight deposits with the central bank in excess of reserve requirements ("excess reserves")—to -0.10%.[15] The rationale behind this rate cut was to further ease monetary conditions by pushing down yields and borrowing costs and to encourage banks to invest in alternative assets, boosting their prices. In the words of Hutchinson and Smets (2017, p. c3), "*the rationale of this measure was that by extending the scope of conventional monetary policy beyond the ZLB, the entire distribution of short-term rates was shifted downwards and additional stimulus could be provided to the economy.*" The ECB further cut its DF rate to -0.20% on September 10, 2014, to -0.30% on December 9, 2015, to -0.40% on March 16, 2016 and, finally, to -0.50% on September 18, 2019.

Short-term interbank rates dropped and entered negative territory soon after the June 2014 cut of the DF rate. The Euro OverNight Index Average (EONIA), a measure of the cost of funds on the

[12] Not only compared to other euro area countries, but also to Switzerland and Sweden, both of which introduced negative policy rates.

[13] In fact, the inflation rate was below 1% at the end of 2013 and further declined in 2014, turning to deflation by the end of the year.

[14] Source: "Market Swing on Trade and Monetary Policy", September 2019, BIS Quarterly Review, Bank of International Settlements.

[15] Euro area banks are required to hold a certain amount of funds as reserves in their current accounts at their national central bank (minimum reserve requirement), which are remunerated at the main refinancing operation rate. Further, they can hold reserves in excess to the minimum reserve requirement either in the Eurosystem deposit facility or as reserve holdings in their current accounts. Differently from the past, ever since the ECB introduced a negative rate on the deposit facility, it treats the current account balances (in excess of the minimum reserve requirement) and the deposit facility in the same way. Both yield negative rates.

Eurozone overnight interbank market, turned negative for the first time in August 2014. Soon after, the one-week Euro Interbank Offered Rate (EURIBOR) became negative as well and stayed below zero for the entire period of analysis (see Figure 1). Around the NIRP announcement, the declines in the interbank rates at one-month and three-month maturities were smaller and both rates remained positive throughout the period.

Importantly, the announcement of NIRP also impacted the middle and long end of the yield curve. In fact, the entire yield curve shifted downward and flattened (see Figure 2). The fall in the yield of safer assets across all maturities widened the wedge between the yields of safer, more liquid assets and those of riskier, more illiquid assets. (We discuss these developments and the role they play in our results in further detail in Section 3.2.)

In May 2014, the growth rate of bank credit to businesses in Italy was negative, at -4.7% on a yearly basis, in an environment of depressed aggregate demand. As shown in Figure 3, immediately after the introduction of NIRP, credit growth picked up, reaching -3.1% at the end of June 2014. While still negative, it continued to rise, reaching -2.3% in December 2014. Besides reflecting demand dynamics, for which we carefully control in the analysis, these developments may have benefitted from other ECB monetary policies implemented around the same time as NIRP. Notably, on June 5, 2014 the ECB announced its TLTRO program and deployed it starting in September 2014. The program aimed at boosting bank credit by offering long-term funding to Eurozone banks on attractive terms. If the TLTRO had an expansionary effect on the economy before its implementation and if banks' take-up of TLTRO funds was correlated with their March 2014 net interbank and liquidity positions, we may incorrectly attribute our estimated effects to the NIRP instead of this policy. To address this potential concern, we control for the TLTRO with a bank-level measure of *ex-ante* capacity to borrow under the TLTRO, derived from supervisory data. Furthermore, Benetton and Fantino (2018) show that while TLTRO reduced the costs of credit for Italian firms, it only did so after the implementation of the second round of the program, that is, *only in the second and third quarter of 2015*, and hence outside our baseline time window. (We discuss the TLTRO in more detail and show our main results are robust to controlling for this policy in Section 4.1.)

Furthermore, a few months later, on January 22, 2015, the ECB announced the expansion of its limited Asset Purchase Program (APP). This policy action, implemented starting March 9, 2015, was widely seen as the start of the ECB's QE, with the objective of providing additional monetary policy stimulus and further easing borrowing conditions of households and firms. Specifically, the ECB expanded its existing, quantitatively limited asset-purchase programs of covered bonds and asset-

backed securities to include public-sector bonds for a total of 60 billion euros worth of monthly purchases.[16] Both the announcement and the implementation of this program are largely outside the time window of our baseline results, so we can rule out the APP affecting our estimates. That said, we also analyze the effects of this LSAP QE policy (in addition to previous conventional and unconventional monetary policies) and compare them with NIRP, in order to understand whether—and why—NIRP is special.

3 Data and Empirical Hypotheses

In this section we explain the different datasets, empirical hypotheses and identification. For empirical identification, we exploit several matched administrative datasets, together with the introduction of NIRP and other policy rate cuts. For the associated mechanisms, we exploit differences in ex-ante bank balance sheet characteristics that are consistent with different channels of transmission (portfolio rebalancing vs. retail deposits), credit supply via volume and loan rates in a within-firm setting, and the change in the yield curve. We also discuss our data and empirical strategy for the analysis of the associated real effects.

3.1 The Credit Register and Other Data

We employ a double-matched administrative bank-firm monthly panel dataset covering the lending activities of Italian banks between 2012 and 2016. The dataset draws on three sources: (i) the loan-level credit register of the Bank of Italy, which reports outstanding loan exposures (with minimum size of 30,000 euros) of all banks operating in Italy vis-a-vis Italian non-financial firms; (ii) supervisory data on bank balance sheets; and (iii) data on firm financials from the proprietary CADS database, owned by Cerved Group, a member of the European Committee of Central Balance-Sheet Data Offices that collects official balance sheet data reported by firms to the Chambers of Commerce, as required by Italian law. All data are monthly, with the exception of firm financials which are yearly and selected bank balance sheet variables which are quarterly (such as capital and net interbank position) or semiannual (income from fees).

[16] The initial asset-purchase programs of covered bonds (CBPP3) and asset-backed securities (ABSPP) were announced in September 2014 and implemented, respectively, in October and November 2014. These initial purchases were so limited quantitatively that only the announcement of January 2015 is considered to be the start of the ECB QE programme, also called LSAP (see, for instance, Altavilla et al. (2015) or Gambetti and Musso (2017)). That said, in Section 4.1 we show that our results are robust even if we consider a very narrow window of one month around the NIRP announcement.

Given the relatively small loan size threshold for inclusion of loans in the credit register, coverage of the credit register is almost universal, comprising all firms with banking relationships. We drop foreign bank branches and subsidiaries (as their liquidity depends on foreign headquarters) and cooperative or mutual banks (as they are subject to different regulations). Our final regression sample contains more than 167,000 firms with multiple banking relationships, borrowing from 95 banks. Loan exposures refer to credit lines, overdraft facilities and term loans.

Data on loan interest rates come from a special section of the credit register (Taxia) and are reported by a representative sample of the largest banking groups and individual banks (covering more than 80% of total bank lending in Italy).[17]

For a robustness test, we also use data from the securities register at the Bank of Italy, with information on the holdings of each security held by each bank in each month, coupled with data on securities yields and prices from Thomson Reuters Eikon, on the basis of which we construct a bank-level measure of windfall gains (defined as profits or losses due to the revaluation of the securities in the portfolios).

Italian banks play a key role in financing the real economy, as most borrowers are small or medium-size enterprises with limited access to alternative sources of external financing. Commercial banks have a traditional business model focused on loan intermediation and banking services. Retail deposits (collected almost entirely from domestic residents) account for 69% of total funding, wholesale funding for 24%, and Eurosystem financing for the remaining 7%. On the asset side, loans to the private sector account for 39% of total assets (with loans to non-financial firms at 60% of the average bank's loan book).

3.2 Identification Strategy

3.2.1 Portfolio Rebalancing vs. Retail Deposits Channel

In the words of the ECB President Mario Draghi: *"negative [policy] rates were introduced for one specific reason: when interest rates reached the zero lower bound, the expectations for the future rates in the long term are only that the rates can go up. So with negative rates we were successful in taking these expectations down"* (Draghi, 2016). NIRP puts downward pressure on the yields of bank liquid assets and shifts

[17] For each credit relationship with commitments above 75,000 euros, banks report two numbers each quarter: first, the amount paid as interest and second, the amount of the loan outstanding times the days the amount was outstanding. If the outstanding amount is 100,000 euros for 45 days and 150,000 for the remaining 45 days of the quarter, the reported number is 100,000×45+150,000×45. By dividing the interest payments by the second number we obtain the interest rate paid on the loan, which we annualize (see Sette and Gobbi, 2015).

banks' risk-reward calculus for asset allocation, with loans becoming more attractive (Bernanke, 2016; Rostagno et al., 2016). However, when interest rates become negative, profit margins can also shrink if banks do not pass through short-term funding rates to retail deposits (Heider et al., 2019; Eggertsson et al., 2019). Therefore, both a portfolio rebalancing channel and a retail deposits channel may operate simultaneously.

We conduct a cross-sectional analysis of bank balance sheets to show that Italian banks with more retail deposits before the introduction of negative rates did not experience a relative decline in profitability in the 6 months after NIRP (Table A1). In addition, we find evidence suggesting that banks were able to compensate for the compression of intermediation margins from incomplete pass-through of negative rates to retail deposit rates with higher fees on banking services. Table A2 shows that banks with greater retail deposits obtain higher income from fees for banking services related to the holdings of deposits in the months following the introduction of NIRP. These findings suggest that the retail deposits channel may be inactive in the Italian context; we directly test this hypothesis in Section 4.

3.2.2 Portfolio Rebalancing Channel and Bank Exposure Variables

To identify the portfolio rebalancing channel, we focus on two measures of bank exposure to NIRP: first, the net interbank position and, second, a broader measure of balance sheet liquidity. Both measures are computed prior to the enactment of the policy.

The European interbank market is very large and is mainly concentrated in short-term maturities (Upper, 2006). Interest rates in this market were immediately affected by NIRP. The one-week Euro Interbank Offered Rate (EURIBOR) experienced the largest drop compared with interbank rates at longer maturities and soon even became negative. Given that banks generally act as both lenders and borrowers in the interbank market (Angelini et al., 2011; Acharya and Merrouche, 2012), we measure bank-level exposure to NIRP with the net interbank position, computed as the difference between interbank loans and interbank deposits with maturity up to one week, divided by total assets. This measure includes all loans and deposits with banks, both domestic and foreign, as well as repos. Interbank lending at maturities up to one week represents about 70% of total activities in the interbank market.

We use the net interbank position because rates on interbank market were immediately affected by NIRP and even became negative. In addition, we adopt a second measure of bank-level exposure to NIRP, namely the liquid balance sheet position, computed as securities divided by total assets.

This measure achieves two purposes. First, it is a broader measure of balance sheet liquidity (in terms of maturities and assets), more sizeable, and more commonly used in the literature of the bank lending channel of monetary policy (e.g., Kashyap and Stein, 2000; Jiménez et al., 2012). Second, the downward shift in the yield curve after NIRP affected all maturities, not only very short-term maturities.[18] Alternative measures of exposure to NIRP, such as the banks' reserve holdings in excess of the minimum reserve requirement, are of limited use in our context as Italian banks effectively did not hold reserves in excess of the amount required by regulation during the sample period.[19]

We compute the net interbank position and the broader liquidity position as of end-March 2014, the closest available date before the implementation of NIRP (on June 11, 2014). Note that our data on bank-level interbank market position are available on a quarterly basis, while data on market expectations show that NIRP was partly expected in May 2014 (Wu and Xia, 2018). In March 2014 the average net interbank position is positive and accounts for 4% of assets, while liquidity accounts for 29% of assets (Table A3). To rule out potential concerns that banks adjusted their liquidity positions ahead of NIRP, Figure A1 shows that there is strong persistence in bank-level net interbank position and liquidity over time: comparing end-December 2013 and end-March 2014 data shows that banks lie close to the 45-degree line. In addition, Figure A2 shows significant cross-sectional variation in pre-NIRP net interbank position and liquidity.

Consistent with a portfolio rebalancing channel and corroborating the choice of exposure variables, in multivariate bank-level regressions we show that banks with more liquid assets before NIRP reduce liquid assets in the months following the introduction of the policy (Table A4). Comparing the net interbank position in March 2014 against the change in the net interbank position in the following 6 months (between March and September 2014) shows that banks with greater ex-ante exposure are more likely to reduce their net position in the short-term interbank market (column 1) and this reduction is achieved by curtailing interbank lending (column 2) rather than increasing interbank borrowing (column 3). Similarly, we find that banks with more liquidity in March 2014 reduce the amount of liquid assets held on their balance sheets between March and September 2014 (column 4).

[18] In our sample, net interbank position and liquidity are weakly negatively correlated. We find similar and consistently robust results if we measure bank-level exposure to NIRP with the sum of these two variables.

[19] Excess reserves in June 2014 account for 0.001% of total assets for the typical bank in our sample, with a highly-skewed distribution (for the vast majority of banks, the share of excess reserves in total assets is negligible). This is not surprising as excess reserves are generally very small in the countries of the periphery of Europe (Baldo et al., 2017).

3.2.3 NIRP, the Yield Curve, and Portfolio Rebalancing Channel

What is different about the portfolio rebalancing channel during NIRP, compared to previous rate cuts just above the ZLB? According to Benoît Cœuré, Member of the Executive Board of the ECB, "*with short-term policy rates approaching levels closer to zero during the early phases of the most recent easing cycle, this channel had become less effective*" (Cœuré, 2017). He goes on to argue that when the ECB changes the key policy rates during normal times, the central bank is able to directly impact the short end of the yield curve, which is the basis of the expectations component. To the extent that market participants see a change in policy rates as the beginning of an incremental series of changes, longer-term rates adjust accordingly. However, in the years before NIRP, market participants believed negative rates were unrealistic and were therefore not pricing the degree of accommodation they normally would have expected. In other words, when nominal rates approach the ZLB, the transmission of short-term policy rate cuts to long-term rates becomes weaker (Ruge-Murcia, 2006).

In Cœuré (2017) words, the "*decision in June 2014 to introduce negative deposit facility rates restored our ability to steer market expectations, [. . .] by signaling to the market that policy rates could go below zero, we ultimately succeeded in shifting downwards the entire distribution of future expected short-term rates, thereby providing important additional accommodation.*"[20] In Figure 2 we document that this was indeed the case. We observe both a downward shift and a flattening of the yield curve only after NIRP and not after the previous rate cuts (above the ZLB) in July 2012 and November 2013 (Figure 4, panels a and b). Rostagno et al. (2016) conclude that NIRP was able to "*rehabilitate monetary policy in the low rate world*". Through their impact on the yield curve, negative nominal interest rates reinstated the transmission of monetary policy and facilitated a reallocation of bank assets, with potential benefits for lending and the real economy. In Figure 5 we show that NIRP was indeed able to generate incentives for portfolio reallocation. The fall in the yield of safer assets of all maturities opened a wedge between the yields on safer, more liquid assets (proxied by Italian government bonds) and yields on riskier assets (loans to Italian non-financial firms). The wedge emerged in May 2014, consistent with the announcement of NIRP being partly expected the month before the announcement (Wu and Xia, 2018). This development is similar with the increase in the safety premium after QE programs of the

[20] Lemke and Vladu (2017) show theoretically that this was indeed the case. By pushing down the effective lower bound, negative policy rates enabled current and future rates to be negative. In their model, the introduction of NIRP makes the forward curve flatter than it would be if short rates are expected to be constrained by a zero lower bound. An event study of yield reactions to negative interest rate announcements shows that long rates tend to drop in response to downward revisions in the market's believed location of the lower bound (Grisse et al., 2017). Eisenschmidt and Smets (2017) make a similar point by showing the empirical discontinuity in the shape of the forward curve around the introduction of NIRP in June 2014.

Federal Reserve, as documented by Krishnamurthy and Vissing-Jorgensen (2011).

In Figure 4 (panel c) we show that a similar flattening of the yield curve took place in January 2015 when the ECB announced its first LSAP QE (via the expanded APP), a feature documented by Eser et al. (2019). In Section 4.4 we conduct a comprehensive comparison between NIRP and other monetary events, including two preceding interest rate cuts near but above the ZLB, and the QE (APP) announcement (see Figure 4). Finally, one may argue that that a flat yield curve puts downward pressure on net interest income in the long run, as the margin between lending rates and borrowing costs compresses (Adrian and Shin, 2010). Despite this possibility, in 2014 and 2015 the net income of large euro area banking groups actually increased. Even net interest income made a positive contribution despite a small decline in interest margins. This reflects an increase in credit volumes after NIRP (ECB, 2016).

3.3 Empirical Specifications

Impact on loan volumes and rates. To identify the effect of negative policy rates on credit supply, we compare loan volumes of banks with different levels of exposure to NIRP before and after the ECB's enactment of this policy in June 2014. Moreover, we also use how banks differently exposed to NIRP change loan rates to the same firm at the same time, i.e. exploiting whether credit volumes vs. rates (depending on bank exposure to NIRP) change in the same way (both increase, consistent with demand), or they change in different way (consistent with supply). We first use the classic Khwaja and Mian (2008) approach and collapse the monthly credit register data into a single pre- and post-NIRP period, with windows of ± 3 and ± 6 months around June 2014.[21] We also analyze other rate cuts (before and after the June 2014 introduction of NIRP), as well as QE. We compute loan growth at the bank-firm level ($\Delta Loan_{ib}$) as the log difference in total loans granted by bank b to firm i between the post- and the pre-NIRP periods, and estimate the following equation:

$$\Delta Loan_{ib} = \alpha \; Net\ interbank\ position_b + \beta \; Liquidity_b + \gamma' \mathbf{X}_b + \phi_i + \epsilon_{ib}, \tag{1}$$

where the measures of NIRP exposure are the net interbank position and liquidity (both defined in Section 3.2.2). Given that our measures of bank exposure to negative rates could be correlated with other bank characteristics (Table A5), to isolate the effect of NIRP on bank credit supply through

[21] Given that the policy was announced in mid-June 2014, we drop all the observations of this month from the sample. We keep the period of analysis relatively short to minimize the impact of other potentially confounding ECB policies. We perform several robustness tests related to the timing of NIRP introduction and the length of windows around it (and we also analyze a very short-term window of ± 1 month); see Table A8 and related discussion in Section 4.2.

the portfolio rebalancing channel, we include the vector $\mathbf{X}_b$ of bank controls, all measured at end-March 2014: bank size (the logarithm of total assets), regulatory capital (Tier 1 capital divided by total assets), and NPLs (impaired loans divided by total assets)—note also that since the model analyzes differences in credit, not levels, we implicitly control for bank fixed effects.[22] Furthermore, note that there is no systematic relationship between a comprehensive set of firm observables (including size, riskiness measured as distance from default, leverage, and profitability) and bank NIRP exposure, measured either by the net interbank position or liquidity (see Table A6).[23]

Shifts in credit demand and other unobserved firm-specific shocks are captured by firm fixed effects (ϕ_i), so the coefficients of interest α and β are identified by comparing the change in credit to the same firm in the same period by banks with different NIRP exposure. Regression estimates are obtained with the Ordinary Least Squares (OLS) estimator and standard errors are double-clustered at the bank and firm level. Double-clustering allows for residual correlation within banks, since our treatment variable varies at the bank level, as well as within firms, given that credit growth to the same firm may be correlated across banks (for firms with many banking relationships and not fully absorbed by firm fixed effects). As shown in the next Section, we subject the baseline specification to many robustness tests.

As explained above, we adopt a similar approach to test for the impact of NIRP on loan rates, where the dependent variable is the change in loan rates applied to loans granted by bank b to firm i between the post- and the pre-NIRP periods, focusing on a ± 6 month window around June 2014. Descriptive statistics for regression variables are reported in Table A3. If the portfolio rebalancing by banks due to negative rates is at work, the supply of credit volume by more affected banks will increase, while loan rates will decrease, consistent with a bank (supply) driven mechanism.

Impact on firm performance. We examine the impact of NIRP on the real economy using several firm-level outcomes and a standard methodology used in the literature on the credit and real effects of monetary and financial shocks (see, e.g., in Khwaja and Mian (2008), Iyer et al. (2014), Cingano et al. (2016), Jiménez et al. (2017) and Jiménez et al. (2019)). We focus on three firm-level outcomes:

[22] While net interbank position is negatively correlated with size, liquidity is negatively correlated with capital and NPLs (Table A5). Moreover, we analyze the same model in other periods to check whether results are driven by NIRP vs. other monetary policies, or by bank unobservables.

[23] We test for the balancing of covariates computing the normalized difference between each quartile average and the average in the other three quartiles. To avoid that results depend on sample size, we follow Imbens and Wooldridge (2009) and analyze the normalized differences—which are the differences in averages over the square root of the sum of the variances. Imbens and Wooldridge (2009) propose as a rule of thumb a 0.25 threshold in absolute terms, i.e. two variables have "similar" means when the normalized difference does not exceed one quarter. Results confirm that firm observables are well balanced across the distribution of bank exposure to NIRP.

total credit growth, net investment, and wage bill growth in the following specification:

$$\Delta Firm\ Outcome_i = \alpha\ Net\ interbank\ position_i + \beta\ Liquidity_i + \gamma' \mathbf{X}_i + \psi_p + \phi_s + \hat{\delta}_i + \epsilon_i, \tag{2}$$

where the first firm-level outcome is the change in total credit growth at the firm level, calculated as the log difference in total bank credit to firm i between the pre- and post-NIRP periods. The key explanatory variables are the firm-level weighted average of the net interbank position and liquidity of all of the firm's lenders, measured before the introduction of NIRP in March 2014. The vector ($\mathbf{X}_b$) includes a set of firm characteristics (size, riskiness, return on assets) and the same bank control variables as in Equation 1, measured before the announcement of NIRP and calculated as weighted averages of the financial variables across the firm's lenders. The firm-specific weights are given by the share of total credit provided by each lender to the firm i in March 2014. In addition to firm's province (ψ_p) and industry (ϕ_s) fixed effects, we account for unobserved growth opportunities at the firm level with estimates of firm credit demand ($\hat{\delta}_i$) obtained from the previous within-firm model of credit growth in Equation 1.[24]

We also study the response to NIRP of net investment, defined as the growth rate of fixed assets, and the growth rate of the wage bill, two key components of aggregate output. We analyze firm-level real effects in the subsample of manufacturing firms;[25] however, for completeness, we report the analysis for the full sample of firms as well. Furthermore, we focus on the ± 6 month window, as firm financial data are available on a yearly basis. The firm-level dependent variables are thus computed as growth rates between end-2013 and end-2014 values.

4 Credit Supply

4.1 Main Results

Baseline Results. Table 1 shows the results from our baseline lending regressions for two time windows: ± 3 and ± 6 months around June 2014. For each case, we start by including separately the net interbank position and liquidity (respectively, columns 1 and 2) and then we include both variables at the same time (column 3).

The coefficient on the net interbank position is positive, statistically significant and stable across model specifications, and indicates that banks with greater net interbank position before NIRP in-

[24] See Cingano et al. (2016) or Bofondi et al. (2018) for further details on this approach.

[25] We use the Ateco 2002 from the National Institute of Statistics (ISTAT), the Italian National Institute of Statistics, which include firms with two-digit industry codes between 15 and 37 in the manufacturing sector.

crease credit supply after the introduction of NIRP more than other banks. The estimated effect of the policy is economically significant. One standard deviation increase in net interbank position is associated with a relative increase of 1.4 percentage points in credit supply after 3 months by more exposed banks (based on the coefficient in column 3 of Table 1). This effect is 1.9 percentage points after 6 months.

The estimated coefficient on bank liquidity is also positive, suggesting that banks with more liquid balance sheets react to NIRP by expanding credit supply more than less liquid banks. The magnitude of the effect of liquidity is comparable to that of the net interbank position, as a change in one standard deviation of liquidity is associated with an increase in credit supply by 0.8 percentage points after 3 months and 1 percentage point after 6 months. Given that the average growth rate of credit was -2.1% over the sample period, these effects are economically sizable.

Overall, the results in Table 1 provide evidence for a portfolio rebalancing channel of monetary policy transmission from liquidity to credit supply in an environment of negative interest rates. They confirm our conjecture that NIRP affects banks through liquidity management. Interestingly, they are also the opposite of how the bank lending channel works in normal times, when banks with more liquid balance sheets react less to monetary policy shocks (Kashyap and Stein, 2000).

The Retail Deposits Channel. As discussed in Section 3.2.1, negative policy rates can also affect banks' credit supply through a compression in deposit margins. Given that banks may generally be unwilling to pass negative interest rates to retail depositors, there is a potential cost associated with higher retail deposits when monetary policy rates become negative (Heider et al., 2019; Eggertsson et al., 2019). To test this channel, in column 4 of Table 1 we control for banks' reliance on retail deposits (as a share of total assets). The results show no evidence of a retail deposits channel across the time windows considered. Moreover, the coefficient estimates on our key NIRP-exposure variables remain unchanged.[26]

The retail deposits channel may be inactive for several reasons. First, despite the fact that retail deposit rates are generally considered sticky at zero, in practice this floor may not bind, neither at zero nor at another level, because of the cost of holding cash.[27] Second, our data show that banks with a funding structure more skewed toward retail deposits (measured in percent of assets in March 2014) increase fees for banking services related to the holdings of deposits after the introduction of

[26] See Section 4.2 for additional evidence inconsistent with the retail deposits channel.

[27] Several German banks were reported to charge negative interest rates on large customer deposits in 2016. See Financial Times (August 11, 2016) and Altavilla et al. (2019).

NIRP, possibly offsetting the income loss from a compression of intermediation margins. Therefore, there is no loss of profitability for banks more reliant on retail deposits (Table A2), in line with recent evidence showing that bank profitability was generally resilient to NIRP (see, e.g. Arteta et al. (2018), Altavilla et al. (2018), IMF (2017), and Lopez et al. (2018)).[28]

Potentially Confounding Policies. As discussed in Section 2, our sample period may raise concerns that other monetary policies confound our results insofar as bank responses to these policies are correlated with their March 2014 net interbank and liquidity positions and affect bank credit. Such worries may extend especially to the TLTRO. The program was announced in June 2014 and was first implemented in September 2014 through 8 quarterly auctions. According to the TLTRO's guidelines set by the ECB, the program take-up has a maximum threshold (or "borrowing allowance") equal to 7% of the total amount of bank loans to non-financial corporations and households (including non-profit institutions serving households) resident in Member States whose currency is the euro, except loans to households for house purchases, as of April 2014.

To control for this policy, we construct a bank-level measure of ex-ante "capacity to borrow under the TLTRO" from supervisory data, defined as the share of the outstanding amount of loans and net lending to euro area non-financial corporations and households, excluding loans to households for house purchase, divided by total assets, as of end-April 2014. In the last column of Table 1, we add this additional variable to the bank controls and show that differences in borrowing limits under the TLTRO do not correlate with changes in loan supply immediately after June 2014. Furthermore, our coefficients of interest (on the net interbank position and liquidity) remain statistically significant with very similar magnitude to the baseline coefficients.[29]

Another relevant ECB policy is the first LSAP QE (APP). However, the QE announcement took place on January 22, 2015, that is, more than 3 months after the end of the time window of our baseline results. As a result, QE is unlikely to affect our estimates. In Section 4.4 we focus on QE to test whether it also affected credit supply through a portfolio rebalancing channel.

To address any residual concerns that our results may be driven by other ECB policies in the time window of our main regressions—such as the second reduction of DF rates, the implementation of the TLTRO or the very limited purchases of asset-backed securities and covered bonds announced

[28]The experience of Denmark and Sweden, in particular, shows that NIRP did not reduce bank profitability due to banks' adoption of higher fees and commissions for banking services (Turk, 2016; Madaschi and Pablos Nuevos, 2017). More generally, the evidence indicates that bank profitability indicators are quite stable and do not react to monetary policy (Drechsler et al., 2018; Zimmermann, 2019).

[29]This is consistent with Benetton and Fantino (2018) who show that banks more exposed to the TLTRO start to reduce interest rates to firms only in the second and third quarter of 2015, beyond our sample period.

in September 2014 (all discussed in Section 2), we shrink the window of analysis. Specifically, we estimate specifications in which we compute loan growth as the log difference in total loans granted between July 2014 (the 1-month post-NIRP window) and April 2014 (the 1-month pre-NIRP window). Given that the introduction of NIRP was already expected by market participants in May 2014 (Wu and Xia, 2018), we drop observations from both May and June from the sample. As seen in Table A7 (columns 1-3), evidence for the portfolio rebalancing channel is present even in this narrow time window, which rules out effects from other ECB policies announced or enacted in September 2014. Furthermore, we continue to find no evidence of a retail deposits channel (columns 4 and 5).

4.2 Robustness of the Baseline

In Table A8 we test the robustness of our benchmark specification for loan volume regressions to a number of different data treatments and subsamples, in an effort to alleviate remaining concerns about identification. In this analysis, we take the specification in column 3 of Table 1, in which we jointly include the net interbank position and liquidity, as our preferred baseline specification, and focus on the ± 3 month period around June 2014.

We start by saturating our preferred baseline specification with control variables for banks' liability structure, namely secured repo funding, bank-issued securities, foreign funding (deposits from non-residents), and interbank deposits (all expressed in percent of total assets). While some of the coefficients on these additional controls are statistically significant, adding these variables leaves our coefficients of interest statistically significant and almost identical in size to the baseline (column 1). Notice that in this specification the coefficient on retail deposits is *positive* and statistically significant at the 10% level, *contrary* to predictions of the retail deposits channel of NIRP.

In columns 2 and 3 we further explore the retail deposits channel. First, we remove net interbank position and leave retail deposits with the standard bank level controls (column 2). Second, we restrict the analysis to large firms (with above-median total assets in March 2014), which makes our results more directly comparable to Heider et al. (2019), whose sample includes large firms that borrow in the syndicated loan market (column 3). In both specifications, the coefficient estimate on retail deposits is *positive* and statistically insignificant, which is further evidence against the retail deposits channel of NIRP.[30]

[30] In unreported regressions we show that the coefficient of retail deposits is negative and significant only when included as the only variable in the 3-month window. Simply controlling for bank size makes the estimated coefficient not statistically significant. We further explore the possibility that the retail deposits channel is at work for banks operating in more concentrated deposits markets or for banks that ex-ante had lower average deposit rates, finding no robust evidence that

Second, we consider the possibility that the announcement of NIRP led to an increase in the fair value of securities on bank balance sheets (windfall gains) with an associated increase in net worth, potentially confounding our results. We first note that that lower policy rates benefit both securities (via prices) and loans (e.g., via a reduction in provisioning, delinquencies and write-offs). In any case, the evidence we find does not support this concern. We show that the profits of banks with ex-ante more liquid assets did not improve relatively to other banks in the months after the NIRP announcement (Table A1). This could be explained by the fact that in Italy, in April 2014, less than 9% of securities are recorded in the trading portfolio, where unrealized gains and losses from price fluctuations are recognized in the income statement. Instead, a very large part of the securities held by banks (more than 40%) are recorded at historic cost. This is consistent with evidence from Bundesbank data on German banks (Tischer, 2018), and from European Banking Authority stress testing data for a broad set of European banks (De Marco, 2019).[31] However, to further reassure that that our result on bank liquidity—defined as securities over assets—is not driven by revaluation gains from the repricing of securities after NIRP, we also explicitly control for a measure of these gains, which we construct following the approach of Acharya et al. (2019).[32] While this measure of windfall gains is positively correlated with liquidity (the correlation conditional on bank controls is 0.24), its inclusion in the model does not affect the estimated coefficient on bank liquidity, which remains positive and significant, and unchanged in size (column 4). An additional argument against this worry is that our estimates of the impact of NIRP are different from those of policy rate cuts above the ZLB, which are similarly associated with windfall gains. More generally, they are different from results on the role of bank liquidity in the bank lending channel of monetary policy for the U.S. (e.g., Kashyap and Stein, 2000) and Spain (e.g., Jiménez et al., 2012).

Third, we consider an alternative timing for measuring bank exposure to NIRP. Measuring bank-level NIRP exposure at end-March 2014 could miss adjustments that banks may have undertaken ahead of the ECB decision to cut its DF rate to negative levels on June 11, 2014. Given that our data on interbank market participation are available on a quarterly basis, the only other feasible date

retail deposits matter for the transmission of NIRP to bank lending in Italy.

[31] Moreover, over the sample period Italian regulations stated that for government bonds recorded at fair value in the available-for-sale portfolio, unrealized gains or losses did not impact the regulatory capital. This rule changed in October 2016).

[32] For each security in the bank's securities portfolio, we calculate the change in price around the NIRP announcement (the difference between the price at end-June 2014 and that at end-April 2014) and multiply these price changes for the holdings of each security outstanding in the bank portfolio before the announcement (end-April 2014). Finally, we add up the individual gains over all the securities in bank portfolios and express them as percent of total equity. Since we also know in which portfolio each security is held, we restrict our analysis to securities held in the marked-to-market portfolios. Further, including the changes in value of the securities recorded at historic costs leaves the results unchanged.

for measuring the net interbank position is end-June 2014. But this is an *ex-post* measure and may reflect adjustments that took place between June 11 and June 30, 2014. That said, using end-June 2014 exposure to NIRP in the lending regressions leaves our main results unchanged (column 5).

In column 6 we estimate the baseline specification with Weighted Least Squares (WLS), taking the logarithm of loan size as weight. The estimates show that the point estimate on the net interbank position and liquidity are similar to the coefficient estimates in the unweighted (OLS) regressions.

Lastly, we consider alternative timings of NIRP. We start by taking into account the fact that the pass-through from negative policy rates to overnight interbank rates was not simultaneous: EONIA turned negative in August. Given that these rates remained positive through most of the period between June and August 2014, we remove observations for these months and redefine the ± 3 window around the period June-August 2014. Column 7 shows that the baseline effects remain statistically significant and close in magnitude to that of Table 1, column 1. In addition, we account for NIRP being partly expected the month before its enactment (Wu and Xia, 2018) by re-centering the baseline analysis on the ± 3 months around May and June 2014—and hence dropping the observations of these months from the sample. Our results are unaffected by the shift of our time window by one month (column 8).

4.3 NIRP vs. Other Monetary Policy Events

Here we examine the extent to which NIRP differs from conventional and unconventional monetary policies. For this purpose, we conduct four additional tests which center the period of analysis on four different monetary policy events. First, we consider the last DF rate cut before NIRP—by 25 basis points to 0% on July 11, 2012. On that occasion, the policy rate cut translated into a decrease in short-term yields, while the long end of the yield curve remained largely unchanged (Figure 4, panel a). The second event, in November 2013, is the last cut of the interest rate on the MRO, from 0.50 to 0.25%, before the DF rate went negative. The interest rate on the MRO was the key reference rate before the introduction of negative rates on the deposit facility. In that event, the rate cut did not flatten the yield curve; if anything, long term yields at end December 2013 increased compared to September 2013 (see Figure 4, panel b). Third, we examine the announcement of the first LSAP QE in January 2015. In that event, the yield curve flattened (Figure 4, panel d), as it did after NIRP, even though the DF rate remained unchanged at -0.20%.[33] Fourth, we test whether the portfolio

[33] Gambetti and Musso (2017) also find that the QE announcement in January 2015 was accompanied by a flattening of the yield curve. The authors explain that the announcement was to some extent expected. However, they also report

rebalancing channel is unique to the introduction of negative rates or, instead, persists after further rate cuts into negative territory. For this purpose, we focus on the most recent episode of monetary easing:[34] in March 2016 the ECB further cut the DF rate to -0.40 basis points. This episode was associated with a further, smaller, flattening of the yield curve (Figure 4, panel e).[35]

The regression results for these tests are reported in Table 2.[36] We find that during the previous rate cuts in positive territory (the first two events discussed above), the impact of monetary policy is very different from our findings for NIRP. For the July 2012 DF rate cut, the coefficients of net interbank position and liquidity are both negative and statistically significant. Liquidity yields a negative and significant coefficient (for the ± 3 month window) after the reduction of the interest rate on the MRO as well. These results are consistent with the standard bank lending channel of monetary policy (Kashyap and Stein, 2000; Jiménez et al., 2012), according to which a monetary easing has stronger effects for banks with an ex-ante lower liquidity buffer (i.e., less need of an ease of monetary policy for banks with higher liquidity as these banks need less extra liquidity to continue lending).

By contrast, after the QE (LSAP) announcement, we find that more liquid banks expand credit supply.[37] However, the coefficient of net interbank position is smaller than for NIRP and statistically insignificant. This result is not surprising given that QE is not associated with a drop in short-term policy rates.

Finally, the effect of the March 2016 interest rate cut is similar to that of the NIRP introduction. The result suggests that the portfolio rebalancing channel is not a one-off effect due to the break through the ZLB, but rather the result of the flattening of the yield curve, which was also achieved, albeit to a smaller extent, in the March 2016 rate cut as well. In unreported regressions, we continue to find no evidence of a contractionary retail deposits channel for the March 2016 event. These results alleviate possible concerns that our baseline finding was caused by rates not being "low enough" or low "for long enough" to dampen bank profitability. In other words, this evidence would suggest

that according to market polls and anecdotal evidence from newspapers, the large scope of asset purchases was not fully expected and hence did surprise the markets.

[34] This is the last episode of monetary easing before the September 2019 rate cut, which we cannot yet analyze.

[35] In the press release that announced the cut of interest rate to -0.30 on December 3, 2015 there is also the announcement of an extension of the APP programme. Since analysts expected a much larger extension of the monthly purchases of securities under the APP programme there was a strong negative reaction in the market on the day of the announcement: the DAX and the CAC 30 lost 3.6% and the Euro appreciated 3% against the US Dollar. This presence of confounding information makes this event less suitable for the identification of the NIRP impact.

[36] Similar to the baseline regressions, we analyze the impact of other monetary policy announcements on bank credit supply in the ± 3 (panel A) and ± 6 (panel B) month windows around these dates. We measure banks' net interbank position and liquidity, in the last available date before the policy announcements, that is, in June 2012, September 2013, December 2014, and December 2015, respectively.

[37] This is consistent with the results in Rodnyansky and Darmouni (2017) and Albertazzi et al. (2018). These papers show that, both in the U.S. and in the euro area, those banks that benefitted more from QE lent more to firms.

that the reversal rate (Brunnermeier and Koby, 2018) has not yet been reached. Even with the DF rate at -0.40% and negative rates in place for almost two years, there is evidence of an expansionary portfolio rebalancing channel and no sign of a contractionary retail deposits channel, similar to the initial DF rate cut in mid-2014 (column 4 of Table 2).[38]

Taken together, our tests suggest that the NIRP announcement, as well as later cuts below zero, activate a portfolio rebalancing mechanism. Banks rebalance their portfolios from liquid assets towards credit supply. This rebalancing behavior is not at play after policy rate cuts in positive territory and close to the ZLB. By contrast, the QE announcement generates effects that are similar to NIRP (in the sense of portfolio rebalancing, but with differences across exposure variables in their suitability to capture the transmission mechanism).

4.4 Falsification Tests

An important identifying assumption in our empirical framework is "parallel trends," which would be violated if our NIRP bank exposure variables were correlated with pre-NIRP loan growth. To rule out pre-existing trends in loan growth for banks with different net interbank and liquidity positions, we run regressions that are similar to our baseline specification (Table 1, column 3), but center the ± 3 and ± 6 month windows on different months before the NIRP announcement. The results are reported in Table A9, which shows the estimated coefficients of the net interbank position and liquidity (both measured at end-March 2014). The top panel considers the ± 3 months window and reports results centered on December 2013, January 2014, and February 2014, the last month for which the post-NIRP 3-month window does not include June 2014 (November 2013-May 2014). For the same reason, the bottom panel reports results for the ± 6 month window around September, October, and November 2013. The results indicate that the parallel trends assumption is valid given that the coefficients estimated in the months before NIRP are generally close to zero and statistically insignificant.

4.5 NIRP and Portfolio Rebalancing Across Euro Area Banks

A residual concern is related to our analysis being based on Italian banks. One could argue that the effect of negative rates may be heterogeneous across the euro area. Differences in deposit rates across banks in different countries, for instance, may make the retail deposits channel more or less effective. Similarly, differences in sovereign risk premia may make the reversal rate (Brunnermeier and Koby,

[38] The estimated coefficients for the portfolio rebalancing are larger in 2016 but the standard deviations of the variables are smaller.

2018) country-specific, so that negative rates are contractionary in some countries, but expansionary in others. To address these concerns, we replicate our baseline analysis in a large panel of euro area banks. The benefit of examining the effect of NIRP across countries comes at the cost of a weaker identification strategy, as with bank-level data, we can neither analyze loan level volumes and prices nor we can properly control for firm-level credit demand with borrower fixed effects.

We collect yearly data on bank balance sheet data from Fitch Connect, for the period 2010 to 2016. After dropping duplicates and cleaning the data (we winsorize all variables at the 1st and 99th percentile), the sample includes 1,838 commercial banks. Using this (unbalanced) sample at the bank-year level, we estimate the following equation:

$$\begin{aligned} \Delta Loan_{bt} \quad = \quad & \alpha_0 \, Liquidity_{bt} + \alpha_1 \, Liquidity_{bt} \times Post \; NIRP_t + \\ & \beta_0 \, Retail \; deposits_{bt} + \beta_1 \, Retail \; deposits_{bt} \times Post \; NIRP_t + \gamma' \mathbf{X}_{bt} + \phi_b + \tau_t + \epsilon_{bt}, \end{aligned} \tag{3}$$

where $\Delta Loan_{bt}$ is the change in the ratio of gross loans over total assets between $t+1$ and t. Liquidity and retail deposits are defined as in the main analysis and scaled by total assets. By contrast, data limitations prevent us from computing a measure of exposure to the short-term interbank market. As a result, the two key variable of interests are the interactions of liquidity and retail deposits with the Post-NIRP dummy (equal to 1 starting at the introduction of NIRP). The coefficients α_1 and β_1 test for the portfolio rebalancing and the retail deposits channels, respectively. The set of bank controls ($\mathbf{X}_{bt}$) mimics as much as possible the main analysis and includes: the ratio of gross loans over assets, equity over assets, the logarithm of total assets, return on assets, and the ratio of NPLs over gross loans. All these variables are included as stand-alone controls and interacted with the Post-NIRP dummy. The model also includes bank (ϕ_b) and year (τ_t) fixed effects. Standard errors are clustered at the bank level.

The results are shown in Table 4, which reports the coefficients of the key interaction terms. The first two columns do not include NPLs as a control variable to maximize sample size, while columns 2 and 4 include a triple interaction with GIIPS countries (Greece, Ireland, Italy, Portugal and Spain) to test for differential lending behavior in response to NIRP. The results in this table confirm our main findings (based on loan-level data) for Italy in a significantly larger sample of European banks. The estimates consistently show that more liquid banks expand lending more after NIRP, even until 2016, with no significant differences between the core and the periphery of the euro area. By contrast, we do not find any evidence that banks more dependent on retail deposits change their lending after the

introduction of negative rates. These results also confirm what found by Demiralp et al. (2019) on a sample of euro area banks.

4.6 Heterogeneity: Firm Risk and Size

Thus far, our findings show that NIRP-affected banks rebalance portfolios away from liquid assets to bank loans. It is important to understand whether banks further rebalance *within* the loan portfolio, in other words whether credit increases homogeneously across firms, or whether it does so more towards certain types of firms.

We focus on two key firm dimensions—riskiness and size—which are relevant for the following reasons. First, riskier and smaller firms are typically more credit constrained and monetary easing should lead banks to expand credit towards marginal, financially-constrained borrowers, too. Second, we would like to pin down the channel driving our results more precisely. If banks rebalance their portfolios towards higher yielding assets, they should expand credit especially towards higher yielding loans. Riskiness and size are good proxies for the yield banks can extract from borrowers because risky and small borrowers are typically charged higher loan spreads and have fewer opportunities to substitute across lenders. We split the sample between (ex-ante) small and large firms, and firms with (ex-ante) weak and strong credit ratings, around the median of the distribution of total assets and that of the Altman z-score respectively (at end-2013).

The results are shown in Table 3, where the first three columns refer to the ± 3 month window and the last three columns to the ± 6 month window. We are testing whether the expansion of credit is stronger for certain type of firms, therefore we include bank fixed effects in all the specifications to absorb unobserved bank heterogeneity and focus on the interaction terms between firm characteristics and the banks' net interbank position and liquidity, respectively. The results consistently show that the relative expansion of credit supply by more NIRP-exposed banks, measured either by the net interbank position (panel A) or by the liquidity ratio (panel B), is significantly higher for ex-ante riskier firms (with high z-score or low credit rating) and smaller firms.

Note that the increase in ex-ante risk-taking by more NIRP-affected banks does not translate into higher levels of ex-post NPLs, even five years after the introduction of NIRP. In Table A10 we report bank-level regressions where the dependent variable is the change in the NPL ratio over one year (top panel) and five years (bottom panel) after the introduction of NIRP and the regressors are bank characteristics at end-March 2014. The results show that more NIRP-exposed banks do not experience a steeper deterioration in loan quality (despite higher lending, and to ex-ante riskier firms), which

suggests that banks do not engage in "excessive" risk-taking, but extend loans to ex-ante riskier yet viable firms.[39]

Finally, we explore the possibility that banks more reliant on retail deposits, even though they do not contract lending, concentrate their lending on riskier firms, as found by Heider et al. (2019). The results—reported in panel C—do not show any significant and robust difference in lending to risky firms across banks with different levels of retail deposits. The coefficient of the interaction term between retail deposits and risky firms is marginally significant (at 10% level), but only for the ± 3 month window.

4.7 Transmission to Loan Rates

Our analysis so far has focused on the impact of NIRP on bank loan volume decisions. But another margin of adjustment is pricing. Eggertsson et al. (2019) use bank-level data and variation in the share of deposit funding across Swedish banks to document a weaker pass-through from the policy rate to loan rates during the NIRP period. By contrast, using loan-level data, we compare the change in the interest rates on loans granted to the same firm by at least two banks with different exposure to the policy, before and after NIRP introduction. Documenting a strong pass-through of negative policy rates to bank loan rates in our approach would further strengthen a supply-side interpretation of the impact of NIRP on bank credit.

Table 5 reports the estimates for net loan rates, separating credit lines and overdraft facilities from term loans. Across columns, our results indicate that negative policy rates affect lending rates through banks' net interbank position and the broader measure of liquidity, although the effect is stronger on credit lines and overdraft facilities than on term loans, as expected. Using the estimates in column 3, a change in one standard deviation in the banks' net interbank position (liquidity) leads to 29 bps (29 bps) reduction of loan rates on credit lines and overdraft facilities after 6 months; this effect is economically meaningful, as it corresponds to almost a 4% reduction (the median net loan rate in 7.9%). In the case of term loans, these effects are smaller and limited to about 5 bps, which correspond to a 1.3% reduction of loan rates after 6 months.

We find qualitatively similar results for gross interest rates, which capture the total cost of borrowing. In this case, the size of the effects on credit lines and overdraft facilities are even larger. A

[39] Another potential source of heterogeneity is bank capital, as banks with lower capital ratios may be constrained in rebalancing their portfolio toward more credit. In unreported regressions, we test whether banks' responses to the introduction of NIRP varies with the level of ex-ante bank capital. We find some weak evidence that the effect of NIRP on the credit supply is larger for high-capital banks, but the results are not robust.

one standard deviation change in the banks' net interbank position (liquidity) leads to 89 bps (62 bps) reduction of loan rates after 6 months, which corresponds to a 7.6% (5.4%) reduction of gross rates on credit lines and overdraft facilities (Table A11).

Finally, our results are robust to controlling for banks' reliance on retail deposits and show no evidence that NIRP affects loans rates through the retail deposits channel (column 4). Hence, the retail deposits channel is inactive both in lending volumes and loan rates, measured either in net or gross terms.

5 Real Effects

Our analysis of credit register lending data shows that NIRP-exposed banks increase credit supply in response to NIRP. But did this positive effect on credit translate into better outcomes in the real sector? To answer this question, we estimate firm-level regressions where the dependent variable is the growth rate of total firm-level credit in the ± 6 month window around June 2014. The net interbank position and liquidity are defined at the firm level as the average net position in the interbank market and average liquidity ratio of the firms' lenders in March 2014, weighted by the share of total credit granted to the firm by each lender. We control for the same (weighted) bank characteristics as in the loan-level baseline regressions, a set of firm characteristics (size, riskiness and return on assets), firm-level demand (measured as the estimated firm fixed effects from the firm-bank loan-growth regressions), and location and industry fixed effects.

The results—reported in the first column of Table 6—show that the coefficients on the net interbank position and liquidity are positive and statistically significant, both in the sample of manufacturing firms (panel A) and in the full sample of manufacturing and services firms (panel B). Using the estimates for the full sample, we find that a one standard deviation change in a firm's lenders' net interbank position (liquidity) is associated with a 2.4 (1.0) percentage point increase in total credit for that firm. These effects are economically large given that the average change in total firm-level credit in the ± 6 month window is 1.7%.

Next, we determine whether more credit translates into stronger firm performance. In the remaining columns of Table 6 we use the same specification but consider the following firm outcomes: the growth rate of fixed assets (investment expenditure, column 2) and the growth of total payroll (wage bill, column 3), which are key components of aggregate output. In the sample of manufacturing firms (panel A) we find that firms borrowing from lenders with greater exposure to NIRP (prior to

the NIRP introduction) expand economic activity relatively more. Looking at the coefficient estimate for the net interbank position, firm investment increases by 6.8 percentage points and the wage bill by 3.8 percentage points more for firms borrowing from banks with (one standard deviation) larger ex-ante net interbank position. Similarly, a one standard deviation increase in banks' ex-ante liquidity is associated with a 4.6 percentage points increase in firm investment and with 1 percentage point increase in the wage bill in response to NIRP.[40]

6 Conclusions

Despite the importance of negative interest rates for our broader understanding of finance and macroeconomics, systematic evidence on their transmission to the economy through the banking system remains scarce. Not only do several major economies (such as the euro area and Japan) currently have negative policy rates and a significant share of global debt trades at negative yields, but NIRP may become even more center-stage in the future given the current low interest rate environment.

We study the impact of NIRP exploiting the introduction of negative nominal policy rates by the ECB in mid-2014, as well as other rate cuts, and comprehensive administrative microdata from Italy. Our main contribution to the literature is to document that NIPR has expansionary effects, and yet differs from policy rate cuts just above the ZLB. The mechanism by which NIRP works is to shift down and flatten the yield curve, thereby incentivizing banks to rebalance their portfolio from liquid assets to lending—a portfolio rebalancing channel. Furthermore, we show that the bank lending channel of NIRP is different from the traditional channel associated with interest rate cuts above the ZLB (Kashyap and Stein, 1995, 2000; Jiménez et al., 2012; Drechsler et al., 2017). We find no evidence of a retail deposits channel (unlike Eggertsson et al. (2019) and Heider et al. (2019)) for loan volumes, rates, or bank risk-taking, even after ECB's last rate cut.

Our main results are as follows. First, we document an increase in the growth rate of total bank credit after the introduction of NIRP with aggregate time-series data. Second, we use loan-level volume and price data to show that NIRP has expansionary effects on credit supply and the real economy through the portfolio rebalancing channel. Differently from previous rate cuts just above the ZLB, the announcement of NIRP shifted down and flattened the entire yield curve, widening the wedge between yields on safer, liquid assets and yields on riskier assets, such as corporate loans. The same portfolio rebalancing channel is also active after ECB's last rate cut (with available data) in 2016,

[40] Results for wage bill growth are similar in the full sample of firms (panel B). This is not the case for investment, as manufacturing firms arguably are more dependent on credit to finance fixed assets.

which went further into negative territory. To further substantiate our findings, we take our analysis to a cross-country setting and show that (ex-ante) more liquid euro area banks also increase credit more than other banks after the introduction of NIRP. Moreover, we show that more NIRP-affected banks expand credit supply more to ex-ante riskier and smaller firms, and cut loan rates, thereby inducing sizable firm-level real effects, including on investment and wage bill, without higher ex-post delinquencies.

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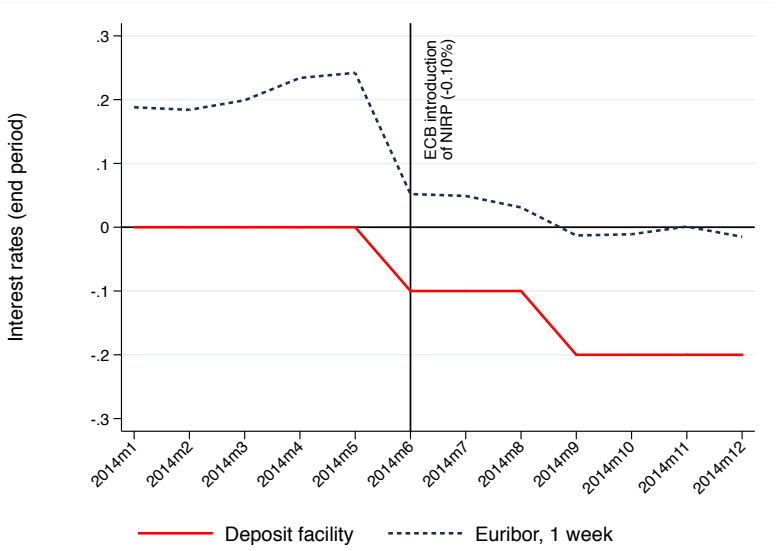
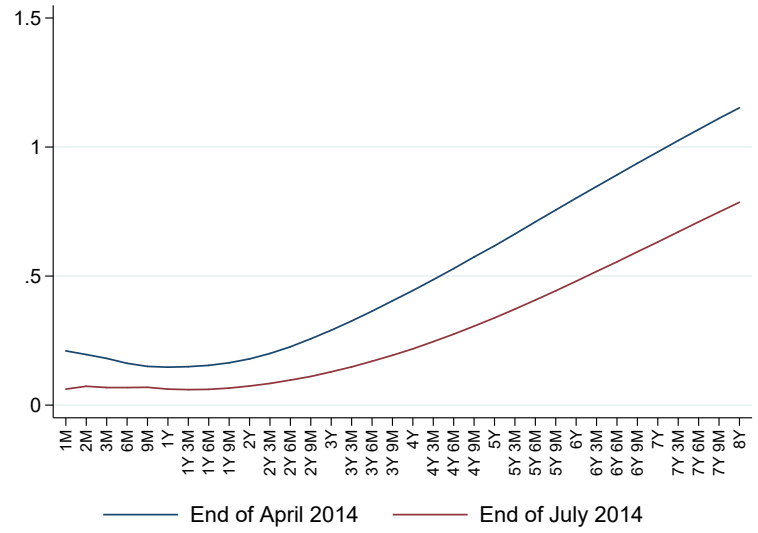
Figures and Tables

Figure 1: Policy and Interbank Rates, January 2014–December 2014



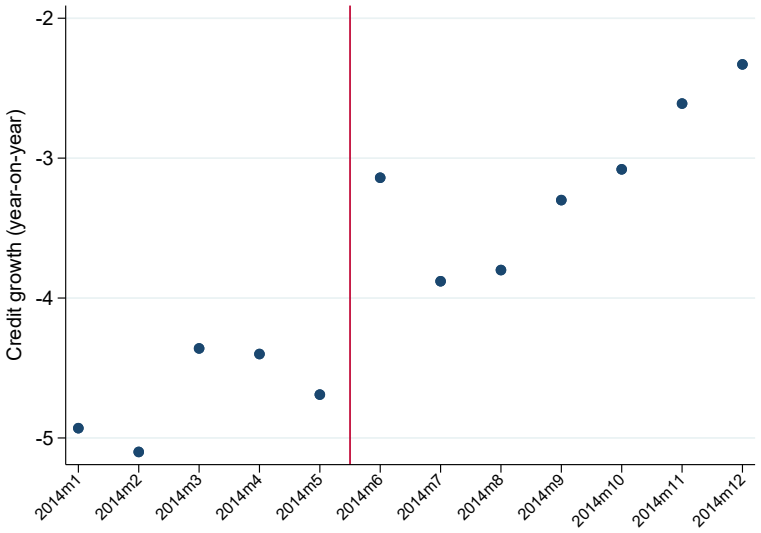
Notes: The chart plots the ECB Deposit Facility rate and the Euribor one-week interest rate, at monthly frequency, taking the end-month values. The solid vertical line corresponds to end June 2014, and separates the pre-NIRP (January 2014–June 2014) from the post-NIRP (July 2014–December 2014) windows. Source: Thomson Reuters Eikon.

Figure 2: Forward Curves with Negative Policy Rates



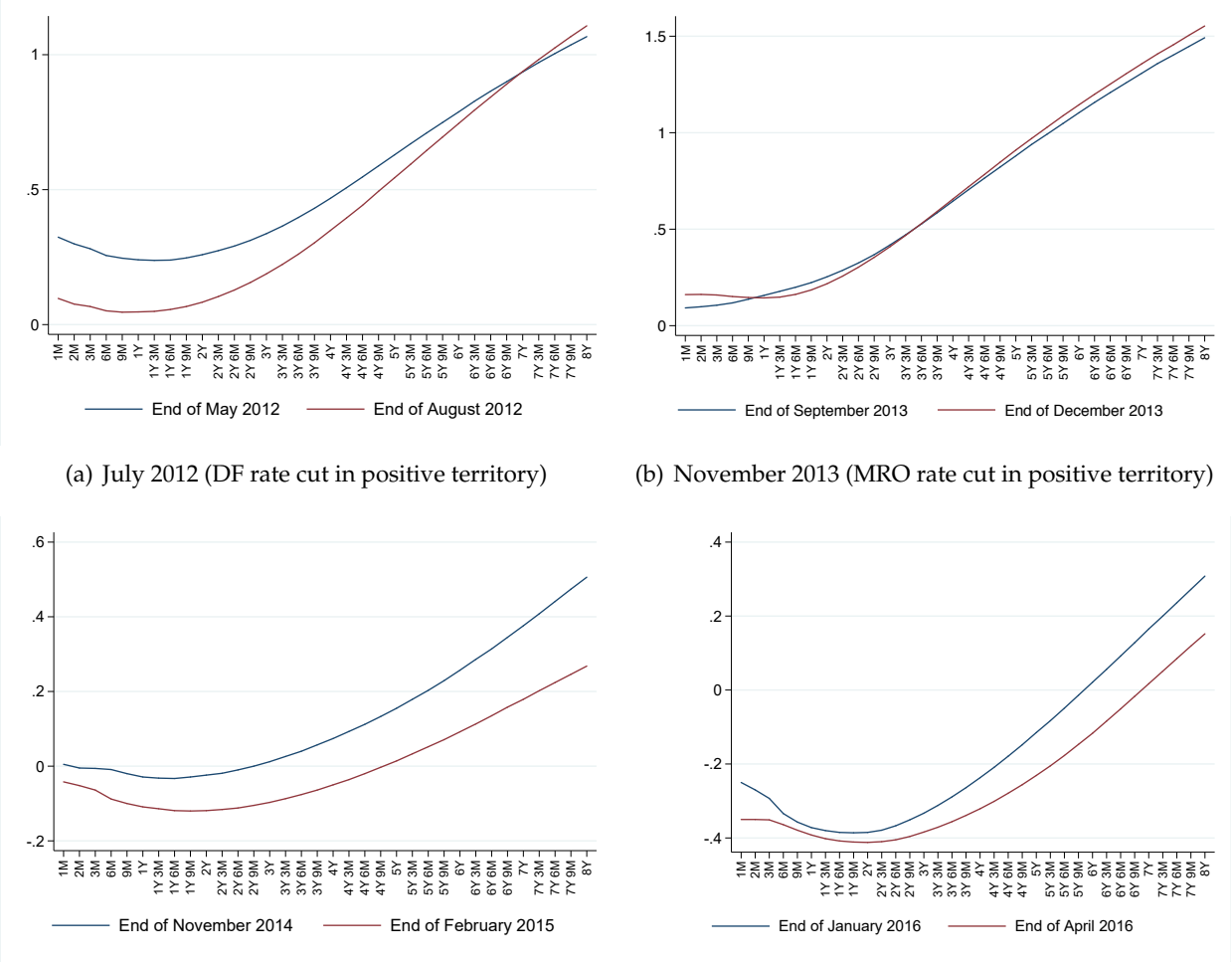
Notes: The charts plot yield curves before and after the ECB introduction of negative policy rates in June 2014. Source: Thomson Reuters Eikon.

Figure 3: Aggregate Credit Growth to Non-Financial Corporations in Italy, 2014



Notes: The chart plots the year-on-year growth rate of total bank credit to non-financial corporations. Source: Bank of Italy.

Figure 4: Forward Curves with Conventional and Unconventional Monetary Policy



(a) July 2012 (DF rate cut in positive territory)

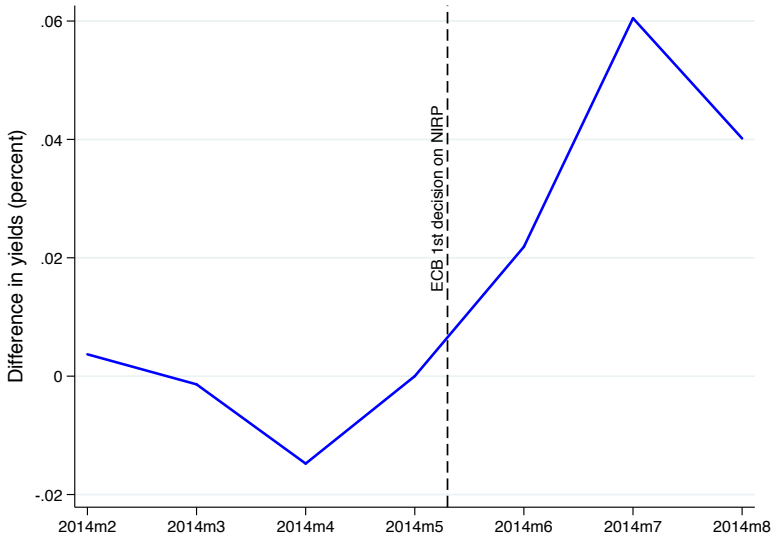
(b) November 2013 (MRO rate cut in positive territory)

(c) Jan. 2015 (QE (APP))

(d) March 2016 (last DF rate cut in negative territory)

Notes: The charts plot the yield curves before and after: the ECB DF rate cut of July 2012 (panel a), the ECB MRO rate cut of November 2013 (panel b), the ECB announcement of QE (expanded asset purchase programme) in January 2015 (panel c), and the ECB interest rate cut of March 2016 (panel d). Source: Thomson Reuters Eikon.

Figure 5: Negative Policy Rates and the Wedge Between Yields on Safer and Riskier Assets



Notes: The chart plots the growth rate of the difference ("wedge") between the average yield on loans to Italian non-financial corporations and that on Italian government bonds, expressed in percent and normalized at 0 in May 2014. Data on market expectations show that the introduction of NIRP in June 2014 was partly expected in May 2014 (Wu and Xia, 2018). Source: European Central Bank statistical data warehouse and Thomson Reuters Eikon.

Table 1: Negative Policy Rates and Bank Credit Supply—Baseline regressions

Notes: The table presents OLS estimates of model 1. The dependent variable is loan growth at the bank-firm-month level, calculated as log difference between the post- and the pre-NIRP period. The length of the pre- and post-NIRP periods ranges between 3 and 6 months, centered around June 2014, which is excluded from the sample. Net interbank position is measured by the ratio of interbank loans minus interbank deposits with maturity up to one week, over total assets, as of end-March 2014. Liquidity is the ratio of securities over total assets, as of March 2014. Retail deposits are measured as a share of total assets, as of March 2014. TLTRO is the ratio of total loans to euro area non-financial corporations and households—excluding loans to households for house purchase—over total assets, as of April 2014. Bank control variables include: i) Size, defined as the logarithm of total assets; ii) Capital, defined as the ratio of TIER 1 capital over total assets; and iii) NPL, defined as non-performing loans scaled by total assets. These three variables are measured as of March 2014. Standard errors, double clustered at the bank and firm level, are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

	(1)	(2)	(3)	(4)	(5)
Window:	±3 **month around June 2014**				
Net interbank position	0.1438**		0.1283**	0.1249**	0.1232*
	(0.0610)		(0.0597)	(0.0605)	(0.0631)
Liquidity		0.0586***	0.0551***	0.0648***	0.0625***
		(0.0179)	(0.0179)	(0.0194)	(0.0208)
Retail deposits				0.0174	0.0243
				(0.0211)	(0.0251)
TLTRO					-0.0141
					(0.0308)
Observations	495942	495942	495942	495942	495942
Bank controls	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
R^2	0.3726	0.3727	0.3728	0.3728	0.3728
Window:	±6 **month around June 2014**				
Net interbank position	0.1972**		0.1778**	0.1720**	0.1683**
	(0.0803)		(0.0771)	(0.0773)	(0.0800)
Liquidity		0.0735**	0.0686**	0.0854***	0.0803**
		(0.0296)	(0.0288)	(0.0322)	(0.0354)
Retail deposits				0.0300	0.0447
				(0.0315)	(0.0363)
TLTRO					-0.0303
					(0.0460)
Observations	498234	498234	498234	498234	498234
Bank controls	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
R^2	0.4009	0.4009	0.4010	0.4010	0.4010

Table 2: Other Monetary Policy Announcements and Bank Credit Supply

Notes: The table presents OLS estimates of model 1. The dependent variable is loan growth at the bank-firm-month level, calculated as log difference between the post- and the pre- monetary policy announcement. The length of the pre- and post-periods is 3 (Panel A) and 6 (Panel B) months, centered around: 1) July 2012, the latest cut of the DF rate in positive territory (column 1); 2) November 2013, the latest cut of the interest rate on MRO before NIRP (column 2); 3) January 2015, the announcement of QE (expanded asset purchase programme) (column 3); and 4) March 2016, the other rate cut in negative territory (column 4). In each model, the month of the policy announcement is excluded from the sample. Net interbank position in the interbank market is measured as the ratio of interbank loans minus interbank deposits with maturity up to one week, over total assets, as of June 2012 (column 1), September 2013 (column 2), December 2014 (column 3), and December 2015 (column 4). Liquidity is the ratio of securities over total assets, as of June 2012 (column 1), September 2013 (column 2), December 2014 (column 3), and December 2015 (column 4). Bank control variables include: i) Size, defined as the logarithm of total assets; ii) Capital, defined as the ratio of TIER 1 capital over total assets; and iii) NPL, defined as non-performing loans scaled by total assets. These three variables are measured as of June 2012 (column 1), September 2013 (column 2), December 2014 (column 3), and December 2015 (column 4). Standard errors, double clustered at the bank and firm level, are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

	(1)	(2)	(3)	(4)
	Panel A: ± 3 months window around:			
	DFR cut in positive territory July 2012	MRO cut in positive territory November 2013	QE (APP) January 2015	Other DFR cut in negative territory March 2016
Net interbank position	-0.2264***	-0.0014	0.0873	0.1619***
	(0.0562)	(0.0476)	(0.0580)	(0.0352)
Liquidity	-0.0866**	-0.0777***	0.0686***	0.1064***
	(0.0403)	(0.0189)	(0.0192)	(0.0218)
Observations	560352	512130	479977	471293
R^2	0.3769	0.3802	0.3671	0.3666
	Panel B: ± 6 months window around:			
	DFR cut in positive territory July 2012	MRO cut in positive territory November 2013	QE (APP) January 2015	Other DFR cut in negative territory March 2016
Net interbank position	-0.2970***	0.0039	0.1320	0.3019***
	(0.0740)	(0.0782)	(0.0797)	(0.0498)
Liquidity	-0.1472***	0.0182	0.0936***	0.1509***
	(0.0529)	(0.0225)	(0.0331)	(0.0391)
Observations	562857	528362	481942	471293
Bank controls	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
R^2	0.3997	0.4054	0.3924	0.3878

Table 3: Negative Policy Rates and Bank Credit Supply—Firm Heterogeneity

Notes: The table presents OLS estimates of model 1. The dependent variable is loan growth at the bank-firm-month level, calculated as log difference between the post-and the pre-NIRP period. The length of the pre- and post-NIRP period ranges between 3 (first three columns) and 6 (last three columns) months, centered around June 2014, which is excluded from the sample. Panel A looks at the heterogeneous effects of net interbank position across firm's rating and size. Panels B and C replicate this analysis considering the heterogeneous effects of liquidity and retail deposits, respectively. Net interbank position is measured as the ratio of interbank loans minus interbank deposits with maturity up to one week, over total assets, as of end-March 2014. The standalone net interbank position and other bank controls—liquidity, capital, size and NPL, as in the baseline (Table 1)—are absorbed by the bank fixed effects, as they are time-invariant (measured as of end-March 2014). Risky firms are defined as those above the median of the Altman z-score (Altman, 1968), measured on a scale from 1 to 9, 1 = best, 9 = worst. Small firms are defined as below the median of total assets. All these splits are done using data as of end-2013. Standard errors, double clustered at the bank and firm level, are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Window:	(1)	(2)	(3)	(4)	(5)	(6)
	±3 **month around June 2014**			±6 **months around June 2014**		
Panel A: Net interbank position						
Net interbank position x risky	0.1532**		0.1473*	0.1503		0.1431
	(0.0764)		(0.0766)	(0.1249)		(0.1262)
Net interbank position x small		0.0994*	0.0892*		0.1340**	0.1201*
		(0.0518)	(0.0516)		(0.0629)	(0.0640)
Observations	439039	441144	439029	440882	442992	440840
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.3670	0.3676	0.3670	0.3944	0.3950	0.3943
Panel B: Liquidity						
Liquidity x risky	0.0633**		0.0596**	0.1125***		0.1114***
	(0.0279)		(0.0282)	(0.0405)		(0.0412)
Liquidity x small		0.0522***	0.0475**		0.0301	0.0211
		(0.0180)	(0.0181)		(0.0240)	(0.0248)
Observations	439039	441144	439029	440882	442992	440840
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.3670	0.3676	0.3670	0.3944	0.3950	0.3944
Panel C: Retail deposits						
Retail deposits x risky	0.0359*		0.0362*	0.0537		0.0532
	(0.0186)		(0.0186)	(0.0324)		(0.0328)
Retail deposits x small		-0.0025	-0.0049		0.0115	0.0079
		(0.0090)	(0.0091)		(0.0095)	(0.0109)
Observations	439039	441144	439029	440882	442992	440840
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.3670	0.3675	0.3670	0.3944	0.3950	0.3944

Table 4: Negative Policy Rates Rates and Lending in the Euro Area

Notes: The table presents OLS estimates of model 3. The dependent variable ($\Delta Loan_{bt}$) is the change in gross loans over total assets at the bank level between $t+1$ and t. Liquidity is the ratio of securities over total assets. Retail deposits are measured as a share of total assets. The Post NIRP dummy is equal to 1 starting in 2013, so that $\Delta Loan_{bt}$, defined as change in loans-to-assets between December 2014 and December 2013, is the first post NIRP period. The set of bank controls includes: i) the ratio of gross loans over assets; ii) equity over assets; iii) the logarithm of assets; iv) the return on assets; and v) the ratio of NPLs over gross loans. All these variables are included as stand alone controls and also interacted with the Post NIRP dummy. The model also includes bank and year fixed effects. Standard errors, clustered at the bank level, are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

	(1)	(2)	(3)	(4)
Liquidity x Post NIRP	0.0342***	0.0327***	0.0394***	0.0365***
	(0.0058)	(0.0055)	(0.0095)	(0.0087)
Liquidity x Post NIRP x GIIPS		0.0415		0.0749
		(0.0841)		(0.1168)
Retail deposits x Post NIRP	0.0025	0.0008	-0.0023	-0.0077
	(0.0054)	(0.0063)	(0.0071)	(0.0086)
Retail deposits x Post NIRP x GIIPS		-0.0313		-0.0169
		(0.0451)		(0.0482)
Observations	10,825	10,825	7,359	7,359
Bank controls	Yes	Yes	Yes	Yes
Bank NPLs	No	No	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes
R^2	0.3994	0.4005	0.4611	0.4646

Table 5: Negative Policy Rates and Loan Rates

Notes: The table presents OLS estimates of model 1. The dependent variable is the change in net loan rates at the bank-firm-month level, calculated as difference between the post- and the pre-NIRP period. The length of the pre- and post-NIRP period is of 6 months, centered around June 2014, which is excluded from the sample. Panel A reports the results for the change in net loan rates on credit lines and overdraft facilities, while Panel B reports the results for term loans. Net interbank position is measured as the ratio of interbank loans minus interbank deposits with maturity up to one week, over total assets, as of end-March 2014. Liquidity is the ratio of securities over total assets as of March 2014. Retail deposits are measured as a share of total assets, as of March 2014. TLTRO is the ratio of total loans to euro area non-financial corporations and households—excluding loans to households for house purchase—over total assets, as of April 2014. Bank control variables include: i) Size, defined as the logarithm of total assets; ii) Capital, defined as the ratio of TIER 1 capital over total assets; and iii) NPL, defined as non-performing loans scaled by total assets. These three variables are measured as of March 2014. Standard errors, double clustered at the bank and firm level, are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

	(1)	(2)	(3)	(4)
	Panel A: Credit lines and overdraft facilities, net rates			
Net interbank position	-0.0349*		-0.0270**	-0.0267*
	(0.0176)		(0.0124)	(0.0133)
Liquidity		-0.0218**	-0.0209**	-0.0211**
		(0.0091)	(0.0087)	(0.0104)
Retail deposits				-0.0004
				(0.0042)
Observations	205091	205091	205091	205091
Firm FE	Yes	Yes	Yes	Yes
R^2	0.3796	0.3821	0.3825	0.3825
	Panel B: Term loans, net rates			
Net interbank position	-0.0059*		-0.0044*	-0.0048*
	(0.0030)		(0.0024)	(0.0025)
Liquidity		-0.0041**	-0.0039**	-0.0036*
		(0.0017)	(0.0016)	(0.0020)
Retail deposits				0.0005
				(0.0013)
Observations	113801	113801	113801	113801
Firm FE	Yes	Yes	Yes	Yes
R^2	0.4100	0.4108	0.4109	0.4109

Table 6: Negative Policy Rates, Firm-level Credit Supply and Real Effects

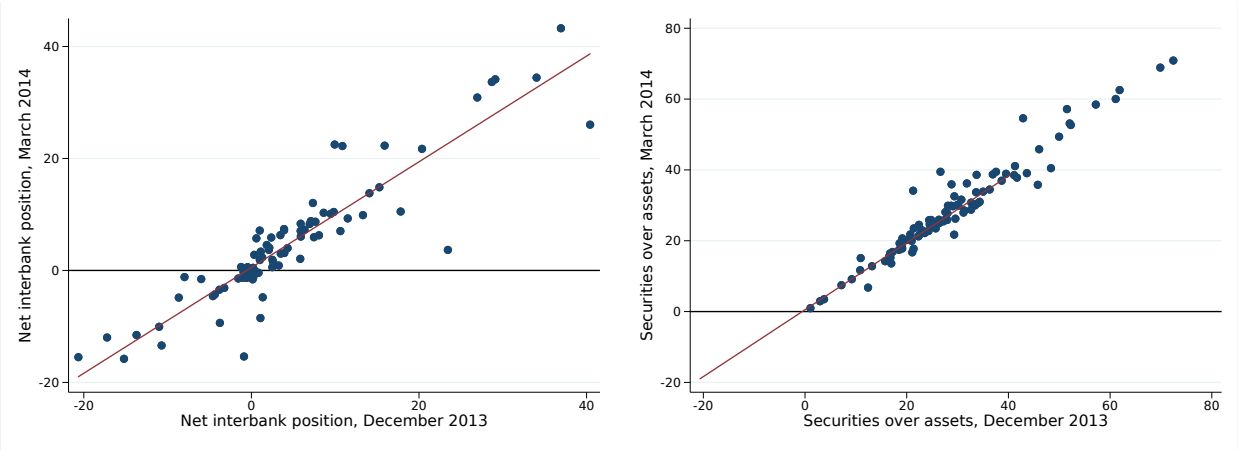
Notes: The table presents OLS estimates of model 2. The dependent variable is, alternatively: 1) loan growth at the firm-month level, calculated as log difference between the 6-month post- and the 6-month pre-NIRP period, 2) net investment, defined as the growth rate of fixed assets between 2014 and 2013; and 3) the growth rate of the wage bill between 2014 and 2013. The set of control variables includes firm characteristics and and firm-level bank characteristics. Firm characteristics include: i) size, measured as the logarithm of total assets; ii) the return on assets; iii) a dummy for risky firms, defined as those above the median of the Altman z-score, measured on a scale from 1 to 9, 1 = best, 9 = worst; and iv) credit demand, measured as the estimated firm fixed effects from the baseline firm-bank loan-growth regression (Table 1, column 1). Firm-level bank characteristics include: i) size, defined as the logarithm of total assets; ii) capital, defined as the ratio of TIER 1 capital over total assets; and iii) NPL, defined as non-performing loans scaled by total assets. These control variables are firm-level averages of bank characteristics, weighted by the share of total credit granted to the firm by each bank, as of March 2014. Net interbank position is measured as the ratio of interbank loans minus interbank deposits with maturity up to one week, over total assets, as of end-March 2014. Liquidity is the ratio of securities over total assets as of March 2014. The sample includes manufacturing firms (Panel A) or all firms (Panel B). Standard errors, clustered at the main bank level, are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

	Panel A: Manufacturing firms		
	Loan growth	Net investment	Wage bill growth
	(1)	(2)	(3)
Net interbank exposure	0.2888***	0.6345***	0.3520***
	(0.0600)	(0.2133)	(0.1070)
Liquidity	0.0563***	0.3272***	0.0665**
	(0.0143)	(0.0989)	(0.0295)
Observations	49701	48134	47350
Firm-level bank controls	Yes	Yes	Yes
Firm controls	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes
Province FE	Yes	Yes	Yes
R^2	0.6327	0.0314	0.0616
	Panel B: All firms		
	Loan growth	Net investment	Wage bill growth
	(4)	(5)	(6)
Net interbank exposure	0.2307***	0.1837	0.3259***
	(0.0473)	(0.2648)	(0.1130)
Liquidity	0.0692***	0.2113*	0.0743**
	(0.0115)	(0.1278)	(0.0303)
Observations	141390	134248	127297
Firm-level bank controls	Yes	Yes	Yes
Firm controls	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes
Province FE	Yes	Yes	Yes
R^2	0.6213	0.0257	0.0624

A Online Appendix—Not for publication

Additional Figures

Figure A1: Net Interbank Position and Liquidity in December 2013 and March 2014

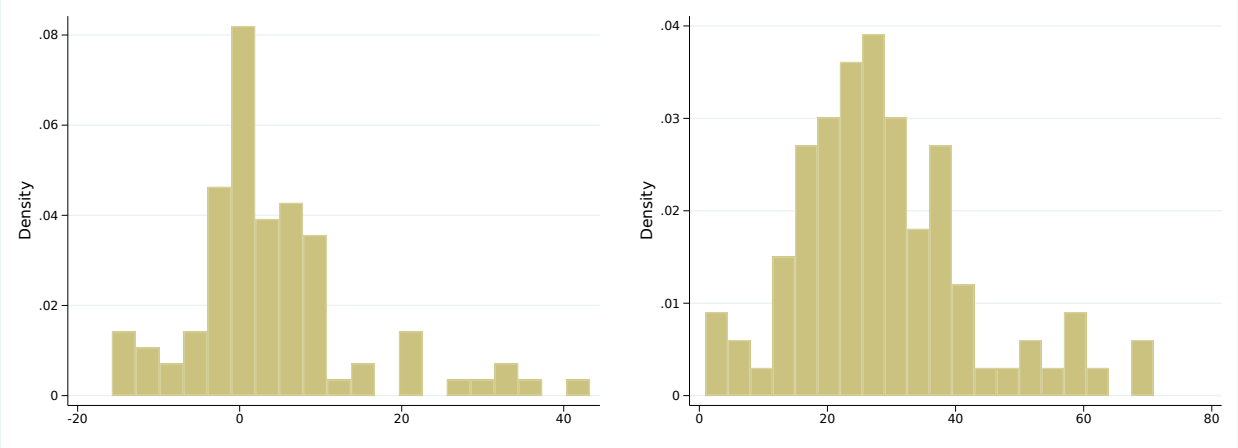


(a) Net interbank position

(b) Liquidity

Notes: The chart plots the correlation between the net interbank positions (calculated as the ratio of interbank loans minus interbank deposits with maturity up to one week, in percent of total assets) and liquidity (calculated as the ratio of securities over total assets, in percent) measured in December 2013 and March 2014. The variables are winsorized at the 1^{st} and 99^{th} percentiles. Source: Bank of Italy.

Figure A2: Net Interbank Position and Liquidity



(a) Net interbank position (b) Liquidity

Notes: The chart plots the distribution of: i) the net interbank position, measured as interbank loans minus interbank deposits with maturity of up to one week, in percent of total assets (panel a); and ii) liquidity, measured as securities in percent of total assets (panel b). Both variables are measured as of March 2014 and are winsorized at the 1^{st} and 99^{th} percentiles. The sample includes 95 banks. Source: Bank of Italy.

Additional Tables

Table A1: Negative Policy Rates and Bank Profitability

Notes: The table shows OLS estimates of a bank-level cross sectional regression. The dependent variables are: i) the change in return on equity (column 1), and ii) the change in the net interest margin over the 6 months following the introduction of NIRP, June-December 2014. The net interbank position, defined as the ratio of interbank loans minus interbank deposits with maturity up to one week, over total assets; liquidity, defined as the ratio of securities over total assets; and retail deposits, computed as a share of total assets, are all measured as of end-March 2014. Bank control variables include: i) Size, defined as the logarithm of total assets; ii) Capital, defined as the ratio of TIER 1 capital over total assets; and iii) NPL, defined as non-performing loans scaled by total assets. Also the control variables are measured before the announcement of NIRP. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

	(1) Δ ROE	(2) Δ NIM
Interbank position	0.3909	0.1345
	(7.1347)	(0.1505)
Liquidity	0.7732	0.1030
	(7.2762)	(0.1248)
Retail deposits	3.1337	-0.0496
	(5.7906)	(0.0857)
Observations	90	90
Bank controls	Yes	Yes
R^2	0.1155	0.1490

Table A2: Negative Policy Rates and Fee Income on Bank Deposits

Notes: The table shows OLS estimates of a bank-level cross sectional regression. The dependent variable is the change in banks' income from fees on bank deposits over the 6 months following the introduction of NIRP, June-December 2014 (data on income from fees is available bi-annually). Retail deposits are measured as a share of total assets, as of end-March 2014. Bank control variables include: i) Net interbank position, defined as the ratio of interbank loans minus interbank deposits with maturity up to one week, over total assets; ii) Liquidity, defined as the ratio of securities over total assets; iii) Size, defined as the logarithm of total assets; iv) Capital, defined as the ratio of TIER 1 capital over total assets; and v) NPL, defined as non-performing loans scaled by total assets. Also the control variables are measured before the announcement of NIRP. Data on income from fees are missing for 12 banks in our baseline sample. If we assume that these banks have no income from fees, results on the full sample of 95 banks do not change (e.g., the point estimates and significance level are almost identical). Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

	(1)	(2)
	Change in fee income from bank deposits	
Retail deposits	0.0031***	0.0024***
	(0.0007)	(0.0007)
Observations	83	83
Bank controls	No	Yes
R^2	0.2111	0.3886

Table A3: Descriptive Statistics

Notes: Panel A refers to bank-level variables. Net interbank position is measured as the ratio of interbank loans minus interbank deposits with maturity up to one week, over total assets. Liquidity is the ratio of securities over total assets. Size is defined as the logarithm of total assets. Capital is the ratio of TIER 1 capital over total assets. NPL is non-performing loans scaled by total assets. Retail deposits are measured as a share of total assets. TLTRO is the ratio of total loans to euro area non-financial corporations and households—excluding loans to households for house purchase—over total assets, as of April 2014. Secured Repo is the ratio of secured repo funding over total assets. Liabilities vis-a-vis non resident is the ratio of foreign funding (deposits from non-residents) over total assets. Securities issues is the ratio of bank-issued securities over total assets. Interbank deposits is the ratio of interbank deposits over total assets. Windfall gain is the sum of individual revaluation gains over all the securities in the marked-to-market portfolios around NIRP as a fraction of a bank's total equity. All these variables are measured as of March 2014. Income fees over assets refer to fees on bank deposits and it is measured as of June 2014. Panel B refers to loan-level variables. Δ *Loan* is measured as log difference between the average total exposure of a given firm with a given bank in the post-NIRP period (July-September 2014) and the correspondent average total exposure in the pre-NIRP period (March-May 2014). *Rate* is the average rate charged by a given bank to a given firm. Gross rates include commissions and fees. Panel C refers to firm-level variables. Δ *Loan* is the loan growth at the firm-month level, calculated as log difference between the post- and the pre-NIRP period. Net investment is the growth rate of fixed assets between 2014 and 2013. Wage bill growth is the growth rate of the wage bill between 2014 and 2013.

	Mean	St.Dev.	Median	Obs.
Panel A: Bank-level variables				
Net interbank position, March 2014	4.200	10.810	1.862	95
Liquidity, March 2014	28.670	13.950	25.940	95
Size	7.667	2.310	7.598	95
Capital	8.533	5.768	7.079	95
NPL	4.348	3.555	3.868	95
Retail deposits, March 2014	45.260	16.120	44.650	95
TLTRO	35.670	12.560	36.370	95
Secured Repo	2.918	8.172	0.000	95
Liabilities vis-a-vis non-resident	1.390	2.240	0.245	95
Securities issued	14.520	10.200	14.560	95
Interbank deposits	13.780	9.785	12.760	95
Windfall gain	1.378	1.525	0.919	95
Income fees	0.124	0.107	0.099	83
Panel B: Loan-level variables				
Δ *Loan*	-2.137	20.435	0.000	495,942
Rate	12.51	5.633	11.642	188,690
Panel C: Firm-level variables				
Δ *Loan*	-1.693	20.380	-0.899	141,390
Net investment	11.463	77.175	-2.564	134,248
Wage bill growth	-1.123	31.991	1.258	127,297

Table A4: Negative Policy Rates, Net Interbank Position, and Liquidity

Notes: The table shows OLS estimates of a bank-level cross sectional regression. The dependent variable measures the change between March and September 2014 of banks': 1) net interbank position (column 1); 2) interbank loans with maturity up to one week over assets (column2); 3) interbank deposits with maturity up to one week over assets (column 3); and liquidity, measured as the ratio of securities over total assets (column 4). Net interbank position is measured as the ratio of interbank loans minus interbank deposits with maturity up to one week, over total assets, as of end-March 2014. Liquidity is the ratio of securities over total assets, as of March 2014. Bank control variables include: i) Size, defined as the logarithm of total assets; ii) Capital, defined as the ratio of TIER 1 capital over total assets; and iii) NPL, defined as non-performing loans scaled by total assets. These three variables are measured as of March 2014. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

	Δ net interbank position after NIRP (1)	Δ interbank loans after NIRP (2)	Δ interbank deposits after NIRP (3)	Δ liquidity after NIRP (4)
Net interbank position	-0.2180**	-0.1644**	0.0536	0.0530
	(0.0851)	(0.0741)	(0.0545)	(0.0501)
Liquidity	-0.0398	-0.0080	0.0318	-0.1016**
	(0.0407)	(0.0369)	(0.0214)	(0.0394)
Observations	95	95	95	95
Bank controls	Yes	Yes	Yes	Yes
R^2	0.1985	0.1643	0.0338	0.1509

Table A5: Net interbank position, Liquidity, and Bank Characteristics

Notes: The table shows OLS estimates of a bank-level cross sectional regression. The dependent variable is, alternatively, the net interbank position (column 1) and liquidity (column 2). The net interbank position is measured as the ratio of interbank loans minus interbank deposits with maturity up to one week, over total assets, as of end-March 2014. Liquidity is the ratio of securities over total assets, as of March 2014. Bank control variables include: i) Size, defined as the logarithm of total assets; ii) Capital, defined as the ratio of TIER 1 capital over total assets; and iii) NPL, defined as non-performing loans scaled by total assets. These three variables are measured as of June 2014. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

	Net interbank position (1)	Liquidity (2)
Size	-2.2878***	-0.3338
	(0.4614)	(0.5773)
Capital	0.2630	-0.8104***
	(0.2178)	(0.2526)
NPL	0.0725	-1.8584***
	(0.3030)	(0.3580)
Observations	95	95
R^2	0.3340	0.2425

Table A6: Balancing of Observable Firm Characteristics

Notes: The table report, for each variable, the average values computed by quartile of bank exposure to NIRP, considering the net interbank position (Panel A) or liquidity (Panel B). Net interbank position is measured as the ratio of interbank loans minus interbank deposits with maturity up to one week, over total assets. Liquidity is the ratio of securities over total assets. Firm size is the log of firm's assets; Z-score is the Altman Z-score (Altman, 1968) computed by CERVED; Equity/Debt is the ratio of the book value of equity to firm's debt; Profitability is the ratio of earnings before interest taxes, depreciation and amortization (EBITDA) to firm's assets. In parentheses we report the normalized differences (the difference between the quartile average and the average of the other three quartiles, normalized by the square root of the sum of the corresponding variances). According to the rule of thumb proposed by Imbens and Wooldridge (2009), two variables have "similar" means when the normalized difference is less than 0.25.

	1^{st} Quartile	2^{nd} Quartile	3^{rd} Quartile	4^{th} Quartile
	Panel A. Net interbank position			
Firm size	7.639 (0.004)	7.721 (0.071)	7.547 (-0.075)	7.642 (0.006)
Z-score	5.118 (-0.048)	5.188 (0.001)	5.142 (-0.031)	5.315 (0.086)
Equity/Debt	0.528 (0.053)	0.487 (-0.009)	0.498 (0.008)	0.453 (-0.060)
Profitability	5.959 (0.005)	5.726 (-0.020)	6.144 (0.026)	5.792 (-0.013)
	Panel B. Liquidity			
Firm size	7.602 (0.021)	7.681 (0.064)	7.568 (0.070)	7.723 (0.057)
Z-score	5.375 (0.102)	5.113 (0.081)	5.256 (0.060)	5.346 (0.086)
Equity/Debt	0.425 (0.083)	0.521 (0.069)	0.464 (0.054)	0.445 (0.057)
Profitability	5.443 (0.041)	5.924 (0.002)	5.958 (0.006)	5.698 (0.0190)

Table A7: Baseline regressions—Negative Policy Rates and Bank Credit Supply, 1-month Window

Notes: The table presents OLS estimates of model 1. The dependent variable is loan growth at the bank-firm-month level, calculated as log difference between the July 2014 (the post-NIRP period) and April 2014 (the pre-NIRP period). May and June 2014 are excluded from the sample. Net interbank position is measured by the ratio of interbank loans minus interbank deposits with maturity up to one week, over total assets, as of end-March 2014. Liquidity is the ratio of securities over total assets, as of March 2014. Retail deposits are measured as a share of total assets, as of March 2014. TLTRO is the ratio of total loans to euro area non-financial corporations and households—excluding loans to households for house purchase—over total assets, as of April 2014. Bank control variables include: i) Size, defined as the logarithm of total assets; ii) Capital, defined as the ratio of TIER 1 capital over total assets; and iii) NPL, defined as non-performing loans scaled by total assets. These three variables are measured as of March 2014. Standard errors, double clustered at the bank and firm level, are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

	(1)	(2)	(3)	(4)	(5)
Window:	±1 **month around May-June 2014**				
Net interbank position	0.1083**		0.0992*	0.0987*	0.0973*
	(0.0512)		(0.0510)	(0.0523)	(0.0545)
Liquidity		0.0356***	0.0329***	0.0343**	0.0323**
		(0.0112)	(0.0110)	(0.0133)	(0.0132)
Retail deposits				0.0025	0.0084
				(0.0145)	(0.0206)
TLTRO					-0.0121
					(0.0245)
Observations	487882	487882	487882	487882	487882
Firm FE	Yes	Yes	Yes	Yes	Yes
R^2	0.3553	0.3553	0.3554	0.3554	0.3554

Table A8: Negative Policy Rates and Bank Credit Supply—Robustness

Notes: The table presents OLS estimates of model 1, with the exception of column 6, which reports the weighted least square (WLS) estimates, taking the logarithm of loan size as weight. The dependent variable is loan growth at the bank-firm-month level, calculated as log difference between the post- and the pre-NIRP period. The length of the pre- and post-NIRP periods is 3 months, centered around June 2014, which is excluded from the sample, except in columns 7 and 8 (where the pre- and post-NIRP periods are centered around June-August 2014 and May-June 2014, respectively). Net interbank position is measured as the ratio of interbank loans minus interbank deposits with maturity up to one week, over total assets, as of end-March 2014. Liquidity is the ratio of securities over total assets, as of end-March 2014. In columns 5 the net interbank position and liquidity are measured in June 2014. Bank control variables include: i) Size, defined as the logarithm of total assets; ii) Capital, defined as the ratio of TIER 1 capital over total assets; and iii) NPL, defined as non-performing loans scaled by total assets. These three variables are measured as of March 2014. Retail deposits are measured as a share of total assets. Secured Repo is the ratio of secured repo funding over total assets. Liabilities vis-a-vis non resident is the ratio of foreign funding (deposits from non-residents) over total assets. Securities issues is the ratio of bank-issued securities over total assets. Interbank deposits is the ratio of interbank deposits over total assets. All these variable are measured as of end-March 2014. In column 3 the sample excludes firms in the bottom half of the sample distribution of total assets, measured in March 2014. Windfall gain, included in column 4, is defined as the change in the value of securities in the marked-to-market portfolio over total equity. In column 7 the pre- and post-NIRP period are computed using a ± 3 month window around June-August 2014, which are excluded from the sample. In column 8, the pre- and post-NIRP period are computed using a ± 3 month window around May-June 2014, which are excluded from the sample. Standard errors, double clustered at the bank and firm level, are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Net interbank position	0.1325**			0.1327*		0.1025*	0.1414**	0.1448***
	(0.0561)			(0.0676)		(0.0608)	(0.0697)	(0.0523)
Net interbank position, June 2014					0.1070**			
					(0.0533)			
Liquidity	0.0836***	0.0696***	0.0561**	0.0558***		0.0524***	0.0697*	0.0588***
	(0.0253)	(0.0191)	(0.0221)	(0.0177)		(0.0199)	(0.0375)	(0.0138)
Liquidity, June 2014					0.0611***			
					(0.0165)			
Retail Deposits	0.0598*	0.0200	0.0171					
	(0.0358)	(0.0207)	(0.0222)					
Secured Repo	-0.0511							
	(0.0664)							
Liabilities vis-a-vis non-resident	0.3049**							
	(0.1261)							
Securities issued	0.0802**							
	(0.0381)							
Interbank deposits	0.0248							
	(0.0431)							
Windfall gain				0.0982				
				(0.2901)				
Observations	495942	495942	269511	495942	495942	441684	483648	498190
Bank controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.3732	0.3727	0.3280	0.3728	0.3727	0.3531	0.3838	0.3742

Table A9: Negative Policy Rates and Bank Credit Supply—Parallel Trends

Notes: The table presents OLS estimates of model 1. The dependent variable is loan growth at the bank-firm-month level, calculated as log difference between the post- and the pre- monetary policy announcement. In panel A, the length of the pre- and post-periods is 3 months, centered around: 1) December 2013 (columns 1-2); 2) January 2014 (columns 3-4); and February 2014 (columns 5-6). We do not expand our sample beyond February 2014 as the ± 3 months window around March 2014 will include June 2014 (and the introduction of NIRP) in the post-period. In panel B, the length of the pre- and post-periods is 6 months, centered around: 1) September 2013 (columns 1-2); 2) October 2013 (columns 3-4); and November 2013 (columns 5-6). We do not expand our sample beyond November 2013 as the ± 6 months window around December 2013 will include June 2014 (and the introduction of NIRP) in the post-period. In each model, the month of the policy announcement is excluded from the sample. Net interbank position in the interbank market is measured as the ratio of interbank loans minus interbank deposits with maturity up to one week, over total assets, as of end-March 2014. Liquidity is the ratio of securities over total assets as of March 2014. Bank control variables include: i) Size, defined as the logarithm of total assets; ii) Capital, defined as the ratio of TIER 1 capital over total assets; and iii) NPL, defined as non-performing loans scaled by total assets. These three variables are measured as of March 2014. Standard errors, double clustered at the bank and firm level, are in parentheses. *** p<0.01, ** p<0.05, * p<0.1. The negative coefficients of liquidity in some specifications can be explained by the fact that, as explained in Section 4.3, in November 2013 the ECB lowered the interest rate on the MRO without flattening the yield curve (see Figure 4, panel b).

	(1)	(2)	(3)
	Panel A: ± 3 months windows		
	Sep 2013-Mar 2014	Oct 2013-Apr 2014	Nov 2013-May 2014
Net interbank position	-0.0097	0.0072	0.0425
	(0.0467)	(0.0482)	(0.0479)
Liquidity	-0.0950***	-0.0678*	-0.0087
	(0.0292)	(0.0367)	(0.0252)
Observations	508784	506734	507318
R^2	0.3787	0.3778	0.3762
	Panel B: ± 6 months windows		
	Mar 2013-Mar 2014	Apr 2013-Apr 2014	May 2013-May 2014
Net interbank position	0.0104	0.0035	0.0296
	(0.0740)	(0.0681)	(0.0665)
Liquidity	-0.0125	-0.0351	-0.0530*
	(0.0221)	(0.0237)	(0.0279)
Observations	522720	518876	514457
Firm FE	Yes	Yes	Yes
Bank controls	Yes	Yes	Yes
R^2	0.4061	0.4062	0.4061

Table A10: Negative Policy Rates and Non-Performing Loans

Notes: The table shows OLS estimates of a bank-level cross sectional regression. The dependent variable is the change in banks' non-performing loans (NPL) scaled by total assets over: (i) the 12 months period following the introduction of NIRP, March 2014-March 2015 (top panel), and (ii) the 60 months period following the introduction of NIRP, March 2014-March 2019 (bottom panel). Net interbank position is measured as the ratio of interbank loans minus interbank deposits with maturity up to one week, over total assets, as of end-March 2014. Liquidity is the ratio of securities over total assets, as of March 2014. Bank control variables include: i) Size, defined as the logarithm of total assets; ii) Capital, defined as the ratio of TIER 1 capital over total assets; and iii) NPL, defined as non-performing loans scaled by total assets. These three variables are measured as of March 2014. Data on the change in banks' non-performing loans is missing for 1 bank in our baseline sample, as the bank is not operative in March 2015. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

	(1)	(2)	(3)
	Period: March 2014 - March 2015		
Net interbank position	-0.0133		-0.0101
	(0.0116)		(0.0242)
Liquidity		-0.0213	0.0102
		(0.0132)	(0.0138)
Observations	94	94	94
R^2	0.0062	0.0260	0.4067
	Period: March 2014 - March 2019		
Net interbank position	-0.0170		-0.0020
	(0.0430)		(0.0442)
Liquidity		0.0313	0.0307
		(0.0314)	(0.0319)
Observations	91	91	91
Bank controls	Yes	Yes	Yes
R^2	0.3759	0.3804	0.3804

Table A11: Negative Policy Rates and Gross Lending Rates

Notes: The table presents OLS estimates of model 1. The dependent variable is the change in gross lending rates, which include commissions and fees, at the bank-firm-month level, calculated as difference between the post- and the pre-NIRP period. The length of the pre- and post-NIRP period is of 6 months, centered around June 2014, which is excluded from the sample. Panel A reports the results for the change in gross lending rates on credit lines and overdraft facilities, while Panel B reports the results for term loans. Net interbank position is measured as the ratio of interbank loans minus interbank deposits with maturity up to one week, over total assets, as of end-March 2014. Liquidity is the ratio of securities over total assets as of March 2014. Retail deposits are measured as a share of total assets, as of March 2014. TLTRO is the ratio of total loans to euro area non-financial corporations and households—excluding loans to households for house purchase—over total assets, as of April 2014. Bank control variables include: i) Size, defined as the logarithm of total assets; ii) Capital, defined as the ratio of TIER 1 capital over total assets; and iii) NPL, defined as non-performing loans scaled by total assets. These three variables are measured as of March 2014. Standard errors, double clustered at the bank and firm level, are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

	(1)	(2)	(3)	(4)
	Panel A: Credit lines and overdraft facilities, net rates			
Net interbank position	-0.1005***		-0.0819***	-0.0815***
	(0.0282)		(0.0157)	(0.0174)
Liquidity		-0.0478***	-0.0449***	-0.0452***
		(0.0136)	(0.0122)	(0.0143)
Retail Deposits				-0.0006
				(0.0053)
Observations	188690	188690	188690	188690
Firm FE	Yes	Yes	Yes	Yes
R^2	0.3959	0.3974	0.3979	0.3979
	Panel B: Term loans, net rates			
Net interbank position	-0.0063**		-0.0047*	-0.0051*
	(0.0030)		(0.0025)	(0.0026)
Liquidity		-0.0042**	-0.0040**	-0.0037*
		(0.0017)	(0.0016)	(0.0020)
Retail Deposits				0.0005
				(0.0012)
Observations	113842	113842	113842	113842
Firm FE	Yes	Yes	Yes	Yes
R^2	0.4094	0.4102	0.4103	0.4103